OBSERVATIONS ON THE REVEGETATION OF MINE-DISTURBED BLM LANDS IN NEVADA

BY

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Table of Contents

Introduction

"Nevada was created because no other concept could separate California from Utah"

The following report is based on my observations of approximately 45 major mine sites on every BLM district in Nevada during the summer and fall of 1992. This work was funded by cooperative agreements with the BLM in Nevada and Barrick/Goldstrike, which operates one of the state's largest mines. Their support, both financial and scientific, is greatly appreciated. The goal of their support was to get an overview of mine revegetation efforts on Nevada BLM lands in the hope of gaining insight into which revegetation techniques are useful and which are not, what constitute reasonable expectations for reveg, and what areas deserve further research to increase the success of vegetation on disturbed sites. I was pleased to find that I was welcome on every mine and at every office that I visited - it is obvious that reclamation is a goal now widely shared in both the mining and regulatory offices. The Agricultural Research Service station in Reno where I was employed for this project, and especially its director Dr. James Young, have provided the perfect climate for this work.

The Federal Land Policy and Management Act (FLPMA) of 1976 set the stage for mine revegetation by requiring the Secretary of the Interior to prevent unnecessary and undue degradation of public lands. The Code of Federal Regulations for mining defines reclamation to include the "revegetating disturbed areas so as to provide a diverse vegetative cover." This is now in the process of being enforced by the collection of reclamation bonds from mines on BLM lands. In Nevada, because the concentration of gold is so small that mines such as Pinson handle 100 tons of rock per ounce of metal, the mines are usually on the surface and very large. The bonds for these operations, which usually cover thousands of acres, range up to $20,000,000 or more for individual operations. The ore reserves consumed are often being replaced by new discoveries at such a rate that mines such as Newmont, with 20,000,000 ounces of estimated reserves, are not decreasing their known reserves. While many of the pits that result from these massive extractions may never be accessible again for non-mining purposes, the processing and office sites, leach heaps, waste rock dumps, haul roads, and exploration accesses will be returned to the public's use after the mines have exhausted their potential. The problem arises that no one knows how to restore the land to other potential uses after such radical disturbance in such an arid environment. No heap leach operation has yet closed in the state, no older mines practiced serious revegetation to provide examples for the learning process, no long term weather records exist for most areas, and everyone agrees that the conditions throughout the state are so site-specific that no one formula or group of formulas will suffice

as instruction on how to grow new plants on old mines. The miners themselves, while recognizing the need for reclamation, are all reluctant to "go first". They are fond of pointing out that no eastern strip mine has ever been released from bonding, despite the extensive studies that have been made on revegetation of such sites in the east, midwest, and intermountain west. Since a typical Nevada BLM district has at least 300 to 400 active notice-level operations (those disturbing less than five acres at a time) and anywhere from ten to 25 "plans" or large mines, there is a lot of land facing reclamation here. Most of these disturbances result from gold mining, but there are also lithium, diatomite, silver, copper, flourspar, clay, turquoise, manganese, and other mines, as well as hundreds of rock and gravel pits.

Most of the mines on BLM land in Nevada are in the salt desert shrub zone. Most of the reclamation specialists and geologists are from other, wetter regions. At Atlas, the engineer summed it up for me. "I was ten years in West Virginia and they've got it made. With 40 inches of rain you can make all kinds of mistakes and things just grow. Mother nature really helps you out there, but not here." Many miners pointed that out to me. "Every time they do a presentation or seminar, there is never anything from the three to eight inch precipitation zone - they come down here to the desert and show us all their nice green slides from northern Idaho." So the miners are learning how to do it themselves, from scratch, all across Nevada. And they are succeeding. In every area, I found miners taking pride in their revegetation work, looking at each others efforts, and showing off their successes. In Winnemucca, Delores Cates says "I firmly believe that if they put the effort into revegetation, it will happen." I agree with that, and I hope that this report simplifies that effort by making the great amount of information that has already emerged from these many reclamation projects in Nevada accessible to everyone who wants it.

Planning

Q: "How long will you be mining out here?"
A: "What will be the price of gold?"

The reclamation permitting process describes most of the considerations involved in devising a revegetation plan and those will not be repeated here. The BLM manuals also describe three types of reclamation in addition to final revegetation: these are concurrent, interim, and supplemental. Interim reclamation is recommended by the BLM for areas which have been disturbed and will be again, but are expected to be inactive for one or more years. It is almost unknown in actual practice in Nevada. Supplemental refers usually to the addition of trees or shrubs by transplanting or overseeding on snow and is discussed in the shrub transplanting and seeding sections. Concurrent reclamation, while uncommon, is coming into greater use for a variety of reasons. It avoids some of the weed and erosion problems that result when the land is left idle for long periods of time. It allows equipment and operators to do the work as they are not occupied with other tasks instead of trying to fit it all in at the end of the mine's life. It reduces the amount of bond being held by getting portions of the bonded area released earlier. And it gives some leeway for the vagaries of weather and other problems associated with revegetation, since there is still time to do the work again if it fails the first time. This also allows the mine to learn from experience, and to modify later revegetation work as indicated from the successes and failures of the earlier work, instead of putting all of the work into one experience at the end.

The type of vegetation sought, of course, depends on the goal for land use post-mining. Although this seems obvious, it is often not considered at all. In most cases in Nevada, the former use of the land would have been to support grazing or wildlife, but this is not true everywhere. On some districts, such as Ely, no other goals are considered, but on others, such as Elko, visual resources are increasingly important, while in western and southern Nevada, all of these are considered, along with the avoidance of introduction of new species into preservation areas. Everywhere, of course, soil stabilization and the preservation of water and air quality is a primary initial goal. And in a few special cases, where a sensitive plant or animal species is present, whether or not it is actually listed as threatened or endangered, a goal of reclamation is to encourage the survival and increase of the species.

Although restoration of livestock grazing is by far the most common goal of revegetation of BLM lands in most of Nevada, many people have commented on the difficulty of justifying it from an economic standpoint, let alone an ecologic one. A typical comment is that "The benefit of restoring production to many of our areas doesn't

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justify the cost, as long as the disturbed areas don't spread out to ruin larger areas." The logic of this is not hard to see: Consider a mine which has a reclamation bond of $2500 per acre, a midrange figure. An AUM might require up to 100 acres or more, and be usable for 6 months of the year, returning grazing fees of $11.16 per 100 acres per year, or 11 cents per acre per year. If no other costs are incurred in the management of this range, the payback would still require almost 22,800 years! This may actually be a conservative example in places near Beatty, where the natural cover rarely exceeds 10% of the surface. In more productive areas there is still real doubt that a successfully reclaimed mine site will evolve into a sustainable community once grazing begins again on it - the plants in use are probably so attractive to herbivores that they will quickly be hammered into oblivion by grazers migrating in off the surrounding less productive ranges. I heard of no examples of revegetated mines on BLM land in Nevada being returned to grazing yet, so only speculation on this problem is available. Thus it is obvious that there may be room for different sorts of goals in arid land mine reclamation.

Similar economics confuse the determination of how much land mines plan to disturb. For example, in 1992, the mine engineers at Round Mountain claimed that if the 8.5% overall royalty specified in the Rahall bill becomes reality, 100,000,000 of their 400,000,000 tons of ore will instantly become waste rock. (Although this bill did not pass, it did clear the entire committee process and will undoubtedly be heard from again - unless it is superceded by other revisions in mining law.) Conversely, if gold rises to $600 per ounce for a sustained period of time, the life of many mines, including Round Mountain and Bullfrog, would be doubled. Under such conditions, concepts such as interim and concurrent reclamation, or seeding schedules, are obviously impossible to plan far ahead. The bonding process creates a real incentive for mines to begin the reclamation process as quickly as possible, though. It is interesting to observe that the mines most resistant to the reclamation process are also the ones who have the most complaints about waiting for it to be finished. For example, at another mine, which began mining in 1989, seeding trials did not begin until late 1992. "It's far too preliminary for us to say how we will do it yet", their engineer told me. "We will try natural invasion because it works so well here - seed is a waste of money so we may not use it." Yet, even after being shown that their "natural invasion" was a pure halogeton monoculture, they said that they weren't "into test plots yet. But we don't want to sit around and watch things grow after we finish- caretakers are expensive!" This approach is a glaring contrast to the success apparent at places like Buckhorn, where test plots were set up with heap material before there was even a heap, or at Barrick and Independence, where dozens of tests are underway with no mine closure in sight.

Pinson, which has a well-deserved reputation for excellent

reclamation success despite the harsh site conditions, began developing seed mixes with consultation from the SCS the year after the mine was designed, and was reseeding new tailings dams a year after that. Every year thereafter saw increased acreage being revegetated and more experimentation and learning underway. The chronologic history of the mine's reclamation work, which they have published, is the best example of how to conduct revegetation in Nevada available.

Other planning considerations involve the geographic layout of topsoil storage and retrieval, the designing of roads to be easy to recontour, and of dumps so that the slopes can easily be reduced. Many of the mistakes in planning result from simple lack of communications, either within the mine, or between the mine and other land users. An example of the former occurred at Hog Ranch, where a very successful project to transplant and propagate the endangered buckwheat was somewhat damaged because the reveg people accidentally put the transplant plot in an area which serves as a survey reference point requiring frequent access. An example of the latter was at the Getchell mine, where a magnificent stand of penstemon on a reclaimed haul road is destroyed annually because the draw in which it is located turns out to be the traditional route by which cattle are brought down out of the high country during the fall gather.

Dirt Work

The BLM manuals for Solid Mineral Reclamation (Chapter 11) and the Manual supplement for Surface Management (Chapter 7) provide basic soil surface and seed bed preparation details. Some refinements to these specifications are important to mention for special cases though. Final dirt work begins of course with general recontouring. The goal of this, in most cases, is to match adjacent land forms so that a natural contour results. As Pete Anderson says, "We like them to look at pre-mine topography and do the dirt work a little creatively to match that. We also like top-dumping at the end to create some mounding as long as no ponding results. The BLM in Winnemucca and elsewhere also favors a non-flat topography, with dips and rolls, which favor plant growth as well as providing visual relief. Dirt work, though, must take into consideration the surrounding topography, as in the broad valleys of southern Nevada, where disturbances virtually disappear if they are flattened and smoothed. Elsewhere it is important to leave trenches and cuts open to preserve evidence of mineralization. Stability of the material is of course the primary goal of recontouring , which often means reducing angle-of-repose slopes to 2.5 or 3 to 1 gradients. In the process, creative operators may add contours and notches, as at Angst near Death Valley, or Pinson at Winnemucca, to duplicate surrounding areas. This requires a sense of perspective and skill which not every equipment operator has. Pinson has an interesting system wherein the operator that does the dirt work also has to do the seeding work, which gives a strong incentive to create a good surface. In the Lone Mountain area near Tonopah the best road recontouring is done when the mines hire the same contractor to build the roads and then again to take them out afterwards. This encourages the contractor to build the roads in a way that makes them easy to reclaim. This contractor also uses a smaller D 6 Cat rather than the usual D 8, so that his impact is lessened from the onset. On steep slopes, trackhoes, although slow, are very effective in recontouring roads, especially when used in conjunction with a dozer so that their efficiency is increased. These also provide the means to scarify the surface with the bucket teeth as a final step to seed bed preparation.

Such scarification, which is also often done with short rippers on a grader on more level roads, is vital to seed success, even though it seems to delay growth in some areas, such as Ely. On roads which do not traverse slopes, sediment control is vital, although easy to ignore in dry years. Waterbars and other diversions of run-off and sediment into acceptable areas will be vital during wetter times, and the BLM surface management manual describes these in detail.

Initial road design and layout is crucial. Where roads have been built directly up the bottoms of watercourses such as at Rocky canyon near Battle Mountain, recontouring may be almost impossible to accomplish. Elsewhere, the most effective method is to pull the berms back up by trackhoe and rip along the contour with waterbars

as needed. Where the cut exceeds three feet, operators can be encouraged to pull the fill side all the way over to the cut. Obviously it is easiest for the design to minimize unneeded cut and fill, so that it is only necessary to pull the berms over the road and contour rip. In cases where this is not possible, the road cuts may be a permanent and prominent feature of the terrain, such as the long haul road for the Cortez mine, which will never be recontoured.

Angle-of-repose slopes are discussed in more detail elsewhere in this report, but are basically very difficult to revegetate both for their steepness and instability. In most cases, they can be avoided by design, although they are apparently unavoidable in cases such as Coeur Rochester's, where the dumps impinge on historic sites and thus cannot be extended. Even in such cases, rounding of the top edges integrates the dumps into the landscape visually so that they are much less obvious. The Solid Reclamation Manual provides specifications for dump benching and design to allow easy final shaping and ensure stability.

High walls and pit sides constitute almost the only landforms for which permanent access restrictions are anticipated. Winnemucca and others have discussed the possibility of blasting down highwalls, since many will begin sloughing anyway. In other cases, wide ledges are left for stability, and for wildlife habitat, which is discussed separately. Other pits will become lakes due to the intersection of groundwater, and will thus be removed from view at least partially. Few mines are considering high wall knockdown or reshaping beyond benching, although Hog Ranch in northern Washoe county is not only knocking down their highwalls but also backfilling the associated pits, which are then recontoured with large Cats. As the BLM personnel there point out, "They are so good at killing the amphitheater look because it's their corporate philosophy - the money for this has been in their budget since day one, so they don't have to find six million bucks for it at closure." Here even the heaps are being unloaded and replaced in the pits, although this is done almost nowhere else, because of the expense, the "swell factor" of processed ore, and the fact that it eliminates the possibility of future mining in the filled pit.

Topsoil placement is discussed elsewhere, but regardless of its availability and placement, careful surface preparation, usually by ripping of one sort or another, is probably the most important factor in determining the success of revegetation, whether it occurs naturally or as a result of seeding or transplanting. Although the BLM Solid Mineral Reclamation handbook recommends ripping to a depth of two to three feet, this is probably too deep in most cases except on badly compacted haul roads and pads. Not only does it bring up rocks which interfere with seeding, but it mixes the usually scarce topsoil deeply and make bring up sodium or calcium-rich substrates which can cause germination problems. The most effective ripping in most cases seems to be close rippers set to rip at one foot or less. Whether on roads, pads, or dump slopes, ripping along the contour is essential. In cases where

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ripping has been done up and down instead, severe erosion is almost guaranteed and vegetation is impossible to establish. In cases where no ripping occurs, surfaces are too smooth, and frequently too crusted, to allow successful seedling establishment. The ideal surface is one with shallow furrows resulting from ripping, and plenty of small to medium sized rocks with topsoil or other fines in between the rocks. On such surfaces it is impossible to tell from the plants whether the seeds were drilled or broadcast in many cases, because even where broadcast, the seedlings are all growing in neat rows where the ripping created furrows. Conversely, more seeding failures in Nevada are due to improper surface preparation than drought, predation, or any other factors.

Topsoil and Fertilizers

"If it's red or gray, bury it - if it's brown, try to save it!" - Mike Zielinski, BLM Winnemucca.

Although topsoil is universally considered to be nearly essential for successful revegetation of disturbed lands, this is often not the case on Nevada's BLM lands. In many areas, the A horizon contains so little organic material or fines that it meets no normal definition of topsoil, while deep alluvial material far from the surface may be equally or more capable of supporting plants. The BLM and Forest Service reclamation manuals describe various considerations in the salvage and storage of topsoils. While soil surveys available at local SCS offices may be of use in determining what to salvage, in most cases the mines just scrape and save whatever looks like it might grow plants. This is usually the top 12 inches or so and any alluvial pockets or lenses encountered deeper. Since some of the best material may be nowhere near the top, the concept of "growth medium" is probably more useful than the term "topsoil".

Ideally, topsoil would be taken up from the salvage site and immediately placed in use where needed elsewhere. This would not only preserve the microflora and the soil seed bank, but would prevent erosion loss and weed colonization of stored soil. In actual fact, I have never seen this done. Thus the storage becomes important. The growth medium should stored in low piles protected from the wind and aligned perpendicular to the prevailing wind direction to reduce wind erosion. The stored soil is required to be labeled by sign as topsoil, to prevent contamination, traffic, and inappropriate use. In cases where the soil will sit throughout a growth season, it should be seeded with a quick and simple cover, such as crested wheatgrass, to control erosion and prevent halogeton and tumbleweed from taking over the soil and filling it with weed seeds. Since herbicides are not generally used on public lands, this is of especial importance. Such growth also preserves the microflora at least to some extent.

Topsoil in many cases is a far from ideal growth medium. For example, at the Sleeper mine in the Slumbering hills, the topsoil contains so much salt that even the weeds don't grow, necessitating the use of underlying alluvium instead. Echo Bay at McCoy Cove also uses alluvial overburden in preference to their topsoil, which is a silty "bug dust" not suitable for plants.
Alluvium also holds water better in some cases than the topsoil. Where the topsoil sets up with a hard crust, it is also unusable, although the addition of gypsum may help prevent the crusting. At Getchell and elsewhere, unadulterated pit material supports good perennial growth. This problem is especially prevalent on limestone soils with calcareous shells, such as on Winnemucca and Ely districts.

It has been observed at several locations that non-topsoiled areas, while slower to show growth, also maintain it further into the

season before it cures. At Buckhorn mine, non-topsoiled areas showed much greater initial species diversity. Here a large test was done using material from the heap, which supported good grass and fourwing saltbush, although the four wing began to die off in about five years on the heap material. Natural reproduction of it was well underway by then, though.

Buffalo Valley mine is another case where the use of topsoil is absolutely contraindicated. Where the bug dust topsoil was spread on the dump top, nothing at all grows. Where the dump surface was only ripped and not topsoiled, there is plenty of grass and four wing where the seed was broadcast. This is also a case where a small test plot would have saved big time and money. Many areas, even where there is useful topsoil, lack enough of it to cover the disturbed areas to the six or twelve inch depth usually recommended. In such cases the question arises whether it is better to use it in thicker, discontinuous patches, or to spread it evenly but very thinly over all surfaces.

At some places, such as Manhattan and Round Mountain, where large areas will never be topsoiled due to the initial lack of salvage and the unsuitability of pit materials, vegetative success may be very difficult to achieve. Here a large experiment with cattle manure is underway and may save the situation. This is further discussed in the section on mulches and amendments. It should be noted here that in areas where topsoil is not used, mulches often seem to be especially important in vegetation success. As the importance of growth medium becomes more obvious, the mines will probably become ever more conscientious in salvaging and storing it. As this occurs, it may be easier for them to prioritize its use, on a first-in/first-out basis, or even to directly place salvaged medium in its final use.

Fertilizer

> "Adding nitrogen for fertilizer in the desert is like giving Tabasco to your mother in law. . . you can do it but you better have plenty of water handy!" - Dr. J. Young

Fertilizer is another variable matter. Although the Nevada DOT [Jack Lane] considers it "an absolute must anywhere in the state" neither the state nor the BLM specify either soil testing or fertilization. Although the SCS or commercial labs or the mines themselves can do the soil testing needed to determine plant nutrient levels, these are rarely done. The Battle Mountain office does ask the mines to analyze top soil stores for N, P, and K, and mines in other areas, such as Ely do test their growth medium. Some BLM personnel feel that it would be a good idea to require basic testing by the mines for their own sake - something simple that could be done in-house by the mine lab. Jarvis in the NMA Symposium Proceedings lists the parameters which a soil lab analysis should include, and also gives the desired characteristics

or range for soil favorable to plant growth. Nevertheless, even the more sophisticated mines rarely either analyze or fertilize their soils, even after multiple seeding failures. One of the most glaring examples of this is at Cerro Duro on the Borealis mine, where a simple analysis of the patches where seedings have consistently failed might give an answer and suggest a mitigation. Where soil analyses have been done, such as at Hog Ranch and Round Mountain, the apparent deficiencies noted are rarely corrected, although Barrick does routinely fertilize based on the nutrient requirements of the soil determined by soil analyses. Nevertheless, nitrogen deficiency is recognized as a common limiting factor in plant growth on disturbed mine lands, and in desert soils in general. The addition of nitrogen sources, such as alfalfa or urea, or even the cyanide solution resulting from heap detox, may make a great difference in plant success. But it may also encourage the alien weeds, which are often more adapted to high nitrogen levels, while the desirable natives are well suited to low nitrogen levels.

Where fertilizer has been used, the results are not always detectable in any case. While some test plots show clearly better vegetation success on fertilized plots than unfertilized, others show no difference at best, or an explosion of weeds at worst. Again, a test plot which uses typical soil from the site and several fertilizer rates along with a non-fertilized control should give the information needed to determine whether or not fertilizer will be of use in a given situation.

Mulches and Soil Amendments

"When they roasted ore in the old days here at Getchell, the arsenic tri-oxide crystals would fall like snow from the sky!"

The BLM Solid Mineral Reclamation handbook and supplement and other sources routinely recommend the use of mulches, usually weed-free straw, over new seedings. The Nevada DOT, well experienced in such matters, specifies that "clean, weed-free, non-moldy small grain straw . . . shall be uniformly applied at a rate of 3000 pounds per acre", which incorporates most of the BLM suggestions. Other mulches sometimes recommended have not always been successful. Paper mulch, used for a time at Newmont, formed an impenetrable crust there and is no longer accepted. At Independence, "We hate paper mulch, but have had fantastic luck with silvafiber on our steep slopes at Big Springs." At Barrick, where several mulch tests have been done, the feeling is that wood mulches are "horribly expensive, in short supply, and have an uncertain future." Alfalfa chaff was felt to be "too stemmy" and to perhaps cause problems with tying up nitrogen for too long. Straw usually involves long hauls, a problem which Newmont plans to resolve by using their pit water to irrigate their Maggie creek ranch lands for the production of local mulch material.

As with fertilizer and irrigation, results from around the state on the use of mulch cover every possible range of success and failure. The issue needs to be resolved on each individual site through the use of test plots. At Borealis, in an unusually wet site, the combination of mulch and top soil was superior to unmulched treatments for the first year of growth, although there was no difference in biomass and cover between mulched and unmulched areas in the second and third years.

John McLain of Resource concepts is a firm believer in the benefits of mulching. "Nothing but straw mulch has worked for us. Netting is very important over mulches, but green netting doesn't hold up. Black netting lasts two or three years. . . you must either use a darn good tackifier or black netting."

Soil amendments are even less predictable in their effects. At Manhattan, the application of seven tons of cow manure per acre may or may not end up helping the perennial vegetation, but "the halogeton really loves it!". Various moisture-holding polymers have generally proved expensive and either useless or actually detrimental, and probably have no applications in Nevada's arid mine areas. The experience with it at Ely district's Casino site is probably typical - "We got great growth for the first month and then it all dried out and died - maybe we set up too much competition for the remaining water."

Gypsum has been used in a few places such as Pinson to reduce the hard crust there, and seems to be at least somewhat useful for

that. Gypsum, which does not cause alkalinity problems, has long been used for the reduction of crusting in agricultural situations. Again, test plots would help to determine how useful this would be in a given situation.

Biosolids from municipal sewer treatment plants have attracted much attention lately as a soil amendment. They have been widely used in the east for years, where they are credited with many positive attributes. In fact, in many mining areas they are now in short supply there! The value of sludge in terms of commercial fertilizer is estimated to be $48 per ton. It has been used on a variety of commercial crops across the U.S. In Nevada, a pilot study is underway to use sludge from the Truckee Meadows sewage treatment plant on the Butcher Boy mine near Wadsworth. This project, getting underway now [1992-1993] should demonstrate whether or not this product has potential as a soil amendment on Nevada mines.

Finally, Dee Gold on the Carlin trend is using the rinse process on its heap at the REN mine to irrigate grasses and legumes which will be plowed under during recontouring once the heap has been detoxed to state standards. The species in use now require too much water to be useful later in final revegetation, but since the water is there anyway at this point, the mine is taking advantage of the opportunity to grow its own "green fertilizer" which should provide organic material, nutrients, and microflora at little cost.

Irrigation

> "Every time a sprinkler head broke the truck drivers would get on the radio and yell that Old Faithful was erupting again down on Green Acres!" - Paul Dusenbury, Round Mountain

The irrigation of revegetation efforts in Nevada is another source of controversy among miners, managers, and scientists. While other agencies, such as the Nevada DOT feel that irrigation is almost essential for reliable seeding success, that feeling is not universally shared on the mines. On the Winnemucca district, "We basically discourage watering. We feel that it's better if we can get it to come up on its own.", says Zielinski. On the other hand, he doesn't feel that the mines should get any consideration for drought conditions. "When we set criteria, they have to meet them, regardless of the weather." Elko district personnel feel the same way. "If they do everything right and there is a drought, you still can't let them walk away. If drought is a problem, they should be ready to get water on it, especially at the mine and mill sites. If you have a thousand acre mine I can't see walking away from it because you only got three inches of rain and nothing came up. Those dry times are when you need to consider irrigation. That's not a new idea around here." Others feel that "it would be OK if they designed the irrigation to match the natural precipitation." Jim Briggs, the SCS plant materials specialist who has dealt extensively with Nevada mine reclamation, does not agree. "On all plantings it should be a contingency that if you don't get natural water you had better be prepared to roll the trucks." The state agrees, according to Pete Anderson. "We do drop hints about irrigation. My personal experience is that success is much higher if you irrigate during that first season." Reclamation specialist Scott Imus, in the NMA symposium proceedings, says that on the drier sites of the Great Basin, "irrigation may be the only way to establish vegetation in most years. . . it may be cost effective in the long run to irrigate some sites and successfully establish vegetation, rather than to experience repeated seedling failures and delay bond release by several years." John McLain agrees with this philosophy. "Irrigation gives you much more leeway in finding that planting 'window'. If we have irrigation in place, we'll seed anytime that it's warm enough. We say don't waste time - get it in and get it watered." Despite concerns that irrigated seedlings will fail when the watering is discontinued, this is not the case at Cyprus Tonopah's test plots in Big Smoky Valley, or at Round Mountain, which have irrigated areas which are flourishing several years after the last artificial watering.

Many mine and BLM personnel have pointed out that most of the mines already have the irrigation equipment and knowhow, since they usually spray the heaps with the cyanide solution during leaching and rinsing. Thus there is often little additional cost, and the equipment can be moved easily from area to area if the mine practices concurrent reclamation. Nor is the water supply a problem in most places, even before the mine is in closure, since

most of the larger pits intersect the ground water and are pumped anyway. (Concurrent reclamation is also a hedge against having to irrigate too much in the first place, since it increases the chances of getting water at the right time at least some of the time, and allows retries with less time pressure.)

In any case, several people have pointed out that after the mines have put so much time and effort and technology and money into the mining part of the process, it seems unnecessary for them to skimp on the reclamation process, even if there is some extra cost in time and materials. Irrigation is common on copper mines in Arizona and elsewhere, and with the bonding process now coming on-line in Nevada, it may prove to be very economical in terms of getting timely and reliable release of bond funds. It may also be useful in getting the required forb component in the reseeded areas, since these seem to be especially strong in irrigated plots in the drier areas such as Round Mountain.

Test Plots

"The younger you are the more chances you take"
Daniel Boone, Nevada DOT

Perhaps the most obvious characteristic which separates successful mine revegetation efforts from failures is the use of test plots. Small-scale tests allow one to see which species and varieties are likely to thrive, whether or not top soil or growth medium is suitable, and whether irrigation or mulch or fertilizer is worth the time and money. As Dr. Young points out, "The basic thing you are trying to do when you establish a plot to test mine reclamation techniques is to : 1) determine which treatment is most successful, 2) determine if the success was due to random chance, and 3) determine why the treatment was successful." One does not have to be a biologist or statistician or even a gardener to use test plots. All it takes is a willingness to experiment and to learn from mistakes. After all, it is much more pleasant to make the mistakes on a small, unbonded plot than on a big waste rock dump where thousands of dollars per acre are riding on the appearance of vegetation. And, as Young says, "The experimental design and statistical analysis does not tell you what treatment was the most successful for mine reclamation. If you can not see what treatment is the most successful by observing the plots, statistical analysis will probably confuse rather than help the situation. What it does allow is determination if the best appearing treatment is due to chance or to some variable that you applied to the test. It allows you to predict the chance of the treatment being successful if repeated under the same conditions." And of course, it allows researchers and regulators to compare results from one site to another. The fact that so much valuable information is in forms that cannot be compared from site to site means that much has to be relearned each time reclamation is done, but the BLM recognizes this as a problem and may be developing suggestions for standardized plots soon. For now, though, test plots are the most vital step in ensuring the success of revegetation, regardless of how they are designed and documented.

Unfortunately, they are still often omitted on the mines. As Pete Anderson says, "The trials are very important, but in many cases the mentality just isn't there." That is even true within the BLM in some cases. On the Winnemucca district, for example, "We have not been big on encouraging test plots on each mine. We encourage concurrent reclamation so that they can learn from that." The problem with that approach is that it discourages experimentation with different variables such as seed, mulch, irrigation, and fertilizer because of the cost of such experimentation. More importantly, it prevents one from a clear view of why a given effort has succeeded or failed, because there is no isolation of variables. As Dr. Young says, "The key to determining why a treatment was successful is to identify and insulate as much of the variability in the experiment as possible. For example, if you are

going to compare the seedling establishment of two different grasses on top soiled waste dumps you plant both grasses on the same soil material, with the seedbed prepared identically and the seeds planted the same way. You further try to isolate sources of variability by holding the slope, aspect, and elevation of the treatments the same. If your test was the influence of topsoiling and not the species of grass, the treatments would be one grass at a time planted with or without topsoil. Again, all other variables would be held constant. You also need to remember that duplicating experiments at different times is not the same as replicating the treatments at the same moment."

On other districts, such as Ely, test plots are encouraged. "They are pretty routine here on Ely district - almost a requirement for a reclamation plan. A test plot in the plan makes approval much easier", according to Lynn Bjorklund. Alligator Ridge, Casino-Winrock, Magma copper, Placer Dome, Alta Gold and others all have them. The idea is to start the plots as they open the mine so that the results are available at closing. And as one miner pointed out, "It's easier for us to experiment when we have no bond over our heads riding on it. We can push heaps around and try things that we wouldn't try if you were holding our money on it." There is a noticeable difference in attitude between mines that are experimenting as they go and those that just hope everything will turn out alright when they plant seed at closure. Some of this was observed on Battle Mountain, where the BLM has observed that "Not many of those guys do test plots. They tend to try to bluff or talk their way past their failures or hope to pass it along to someone else." The other extreme is represented by mines like Buckhorn or LAC Bullfrog. At LAC "We got started early with lots of ideas to see what works so we don't get stuck spending hundreds of thousands of dollars for seed that will never come up while we delay our whole closure." This approach is discussed in greater detail in the section on planning.

From a scientist's standpoint, almost all of even the successfully executed test plots on Nevada mines have been plagued by design and evaluation flaws which have nearly eliminated their value to researchers outside the mine. Lack of replication, failure to identify the physical, biological, and chemical characteristics of the test sites, inconsistency of slope, aspect and terrain between tests, and failure to record such details as seedling emergence/mortality, soil moisture and temperature, seed and seedling predation, or the amount of mulch and fertilizer have frustrated scientific efforts to learn to predict what factors cause revegetation to succeed or fail. Dr. Young says that "We need to know why seedings fail or succeed in relation to measured environmental parameters. We have to arrive at this information through a procedure that permits an assessment of the probability that the results can be repeated."

Of course the mines have different goals for their tests than do the scientists. . . they just want to see what will come up on small patches before they do the whole waste dump. But even those

efforts are sometimes defeated by lack of consistency in the tests. At LAC Bullfrog, the test plots on the tailings dam all had different aspects. Thus it was impossible to determine if the excellent shadscale invasion was due to differences in the fertilizer or seeding or the direction which the plots faced. Such differences are of course significant - at Barrick, the north aspects are usually five weeks behind the west in spring green-up. Well designed plots, such as Barrick's, encourage the reclamation staff to analyze the results in quantifiable terms such as cover, biomass, density, and frequency so that the trend can be watched over time. By contrast, a stone's throw away at Newmont, the environmental coordinator bemoans his lack of perspective on the vegetation trends there. "I wish I had the people and the time to check it. I don't know if it's getting better or worse." A lack of record keeping is one of the sources of this problem. "I have that in my files but I don't think I could find it" is a common answer to many reclamation questions. This problem is not confined to the smaller mines - several of the largest mines in the state have lost nearly all of the information in their test plots through lack of marking, mapping, and note-taking. Problems with marking are especially common and are also discussed elsewhere. Nor are they confined to test plots done by miners - even at the Beacon Hill test plot near Battle Mountain, which was set up by scientists, it is impossible to find the markers and boundaries of the various seed trials and treatments. Similar problems confuse the results on many of the SCS test plots in Nevada. While this is not as disastrous on the SCS plots, which usually are set up only to test the germination and survival of different plant materials, it is of great consequence when it prevents a mine from knowing how their plants responded to different fertilizer, mulch, topsoil, or irrigation regimes.

Actual test plot design and layout is as varied as mine designs themselves. Ideally there should be one test plot for each area of the mine that differs in geology, elevation, aspect, or disturbance. Thus there would be one for each waste rock dump, mill site, haul road, and heap, and probably one for each side of features that have different aspects. In their simplest forms, these plots would use whatever seed mixes, planting methods and rates, and soils and mulches are being considered for the main revegetation work. The plot site preparation - grading, ripping, growth medium application, etc., should be done with the same equipment (and if possible, the same personnel) as the main work will be done by, even if the small size of the test would make it more efficiently done by other equipment. A typical plot layout might include areas of no topsoil, thinly spread topsoil, and thicker topsoil. In <u>each</u> of those areas, there would be an unseeded area, an area of seeding at the recommended rate, and perhaps an area of seeding at half and at twice the recommended rate. Each of these would then have areas of fertilizer at perhaps several rates as well as an unfertilized area. And each of the resulting plots would again be divide into areas which are mulched and not mulched. If irrigation is being considered, the whole set of plots could again be divided, so that for each combination of

treatments there would be one which would be watered and one left dry. For ease of layout, it may be easiest to make the plots in multiples of equipment passes, for example, two passes by the grader or cat being used to prepare the surface for the width of each soil treatment, perhaps separated by a one-pass width of bare area for ease in marking, movement of equipment, and irrigation set up. The design proposed here, with two seed mixes, three soil layouts, two seeding rates, two fertilizer rates, mulch vs. no mulch, and irrigation vs. non-irrigation, would in a small area try 96 different combinations not counting the control, or untreated area! Obviously it is very important to prioritize, mark, and map the different plots so that when some of them greatly outperform others one can determine what combination of factors lead to the success so that one can repeat that treatment accurately on a larger scale. Even simpler designs with only one seed mix, a couple of seeding rates, fertilizer and mulch, will still include far too many combinations to be trusted to memory or a map with no reference points on the plot. Of course, once some of the treatments have been shown to be less effective than others in early tests, they can probably be eliminated in later ones, simplifying the layout of test plots. But there is some danger in ruling out too many, since what works in one place at one time may not work elsewhere at another time. If things were that consistent, test plots wouldn't be needed in the first place! As early tests are evaluated though, it becomes less risky to increase the size and decrease the complexity of later ones, so that one can use, for example, an entire waste rock dump as a test without too much fear that it will all turn into an expensive failure. Pinson and McCoy Cove are both notable for having large test plots which are consistently successful enough to make further reveg work on those plots unnecessary. The size and success of these plots also allows them to serve as valuable seed sources, not only for spontaneous spreading of the species, but also for collection by the reclamation personnel for use elsewhere on the mine. Besides saving money, this makes it more likely that one is getting a good variety, since it is one that has already proved itself in the same situation.

Of course, many existing test plots are much simpler, or at least more spread out. For example, a mine may have different areas in which they test topsoil on one site, alluvial material on another, and waste rock on another. Or they may have ruled out mulching and irrigation for some reason. Nevertheless, the more that can be tested under the same conditions of location, timing, and equipment, the less likely it is that differences in the results are due to other variables than those which were intended. Thus when certain plots do much better than others, one might be more certain, for example, that it was the use of mulch and fertilizer that made the difference, and not the difference in weather the first spring after two areas were planted several months apart.

In the section on planning, the importance of an early start on test plots in the mine's life is discussed at length. The other side of this is that continued follow-up of older plots is also

vital. On a test plot near Elko, for example, it was observed that non-topsoiled areas had much more species diversity than top-soiled areas for the first few years. The most successful single species the first year was crested wheatgrass, on the topsoiled areas, with no difference in 3 or 6 inches of soil. By the fifth season, four-wing and invading sage had exploded on the topsoil areas, but the biggest fourwing on the non-topsoiled areas were beginning to die out. It was also observed that topsoil areas greened up faster in the season but also cured out sooner in fall. Where there was no topsoil, mulch greatly improved success, while it made little difference on topsoil plots.

Other examples of test plots : At Casino, on Ely district, where a waste dump included two test plots, because of differing soil conditions, to test soil amendments. The test strips here included: Control area - earthwork only; topsoil without seed; topsoil and seed (two different strips); no topsoil with seed (two different strips); topsoil, polymer, seed (two different strips); and no topsoil with polymer and seed (two different strips), for a total of six combinations. (The identical strips were originally planned to be fertilized and unfertilized, which would have made a total of ten combinations, but this was not done.) Other tests on the same mine were done to evaluate seed viability and application rates, side slope stability, and various other factors. Drill roads were tested in five 60 foot sections, with five different seed mixes.

At Round Mountain, a test plot included five treatments: no topsoil and no seed; no topsoil with seed mix no. 1; topsoil with seed mix no. 2; topsoil with no seed; and no topsoil with seed mix # 2. These 50 X 100 foot tests reflect attempts to investigate specific ideas observed in earlier tests.

At Cyprus Tonopah, one seed mix was tested. The treatments were fertilizer, seed, mulch; seed and mulch; seed and fertilizer; and seed only. Each of these five treatments was then irrigated in one area and left dry in another.

At Grefco, testing was done to determine suitable species for revegetation of the diatomite "bug dust" which makes up the site. Fifteen individual species were tested in two adjacent test plots, one armored with rocky alluvial and one with un-armored diatomite waste.

At LAC Bullfrog, a variety of test plots in different areas test various concentrations of hydromulch, tackifier, fertilizer, and soil conditioners on different surfaces in their very dry environment.

At Cominco a test was designed to test the revegetation potential of their agglomerated heap material. A two-foot layer of spent heap material obtained early in the mine's life was placed on a 190 X 300 foot plot. This was divided into three sub-plots, 100 X 180 feet, one of which got a six inch layer of topsoil while another

got three inches. The third was left bare. On each of the resulting plots 12 individual treatment plots, each 60 X 25 feet, were then tested with various combinations of fertilizer, mulch, and seeding.
A recording rain gauge was placed beside the plot. The whole area was livestock-fenced, to which chicken wire was added to exclude rabbits.

At Echo Bay's Borealis mine, very extensive tests investigated many combinations of topsoil, spoil, mulch, and different fertilizer and seeding rates, both with numerous seed mixes and a wide variety of individually planted grasses, shrubs, and forbs. These tests were conducted not only on top of the dumps, but on the various faces of them as well and represent the most detailed and complicated series of tests which I observed during this study. Not surprisingly, the mine has been widely recognized for its outstanding success in the revegetation field, although the higher and wetter environment in which it is located is a big help. But the same company's McCoy Cove mine in a very dry area near Battle Mountain has received similar recognition, as has Pinson, near Winnemucca. Both of these operations practice extensive test plot investigations concurrent with active mining. While the more complicated plots at Barrick, Cominco, and Borealis were designed and implemented with the assistance of research scientists from various federal agencies, the others, all of which have been very useful to the mines who set them up, were done without outside help. Even the simplest approaches, such as Grefco's, are giving the mines the information they need to cheaply and reliably meet their obligations to revegetation, in spite of the hostile environments in which many of them are operating.

The same range of complexity and sophistication can also be observed in the evaluation of the test plots. This ranges from the simplest "eyeballing" of plots, such as the SCS uses on their field trials, which are described as "good", "fair", or "poor", through the use of ten-point frames at Cominco to obtain cover data, to a combination of line intercept transects, biomass weights, seedling height, and density at Casino, along with almost every other possible combination of parameters at other locations.

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Native versus Exotic Species

"Well, we all know about Carter's executive order on the use of native species, but back then we all hated the Russians. Now we feel sorry for them and should maybe buy their plants!"
- Paul Dusenbury, Round Mountain Gold.

On May 24, 1977, President Carter issued Executive Order 11987, which states that "Executive agencies shall, to the extent permitted by law, restrict the introduction of exotic species into the natural ecosystems on lands and waters which they own, lease, or hold for purposes of administration; and, shall encourage the states, local governments, and private citizens to prevent the introduction of exotic species into natural ecosystems of the United States." This order has never been rescinded. Yet both the Forest Service and BLM rely heavily on exotic species in some areas. On the state level, Pete Anderson says "We are for either natives or adapted exotics - we have too many cases here where if you can get anything to grow it's better than nothing." He further says that the state has no formal policy on the matter, and would follow the agency lead "if they made a recommendation". On the Winnemucca district, "We are not constrained to natives - our mineral policy says that we must be economically reasonable, which rules out many natives". At Tonopah, "We don't have a native policy- we are sort of stuck with them because most exotics need over eight inches of precip. But above that level the crested wheatgrass does so well I'd hate to see it not used. I don't think that the original climax community is always the best use of the land, especially from a grazing standpoint." Not everyone in the BLM in Nevada agrees, of course. On the Las Vegas district I was told "My personal opinion is that you should not be allowed to use non-natives . . . our list of seeds is all native." Ely district is similar: "The policy here is to use native species." Susanville district says "We don't have a policy, but we would love to have one." Battle Mountain is "Going with natives where we can. We try to put back whatever has already been growing there. We are steering away from crested wheatgrass - have been for several years now." At the Nevada DOT, Jack Lane says "We've done thousands and thousands of acres of seedings - we couldn't get the results we needed with natives. So we went with grasses and let the natives volunteer in over them." Daniel Boone of the same agency says, "We did tests with native plants all over the state - the success rate was usually around one to five percent!" But he points out that the highway environment is very different in terms of pollutants, water, and traffic from the desert that it runs through. At Grefco, near Tonopah, all of the species in the test plots that did well were natives, except for Kochia. In wetter areas, surprisingly, they may be more difficult. At Independence near Elko, "We had no glaring species failures but did have more trouble with some of the natives." Nevertheless, at the NDF nursery Greytak is sure that "as the ecologists get the upper hand, we'll be more aware of the need for local native seed." The Park Service is already very concerned with the introduction not just of

exotic species, but even of exotic genetic material in natives. At Gold Bar/Angst, adjacent to Death Valley National Monument, they asked the BLM to avoid any seeding for that reason. (This has created the largest reservoir of Russian thistle to be seen for miles, ironically enough. But some of the topsoil piles awaiting redistribution there are growing native perennials, with several species evident already.) The U.S. Fish and Wildlife Service, which frequently takes the agency lead in such issues, also stresses the importance of local collection of seed, while pointing out that no final regulations relating to the Executive Order were ever published. Mary Jo Elpers there refers to the lack of official direction, and says that one must consider the end goal as a choice between reclamation and restoration. "If you want to restore the natural system, you must use natives. But many sites are too disturbed to ever get the natural system back. Nevertheless, there are concerns about biodiversity. On mine sites, a non-native may have implications for the biodiversity of adjacent undisturbed areas. We don't have an official position on this here, but we don't want to lose those areas - it could result in additional listings of endangered species. It's a political wait-and-see situation."

The problems of availability of native seed, also discussed elsewhere in this report, might best be solved by local collection. Unfortunately, at this time, this is very impractical both from the technological and economic standpoint. But several mines have made good use of local seed both from on and near the mine sites. Independence has collected thousands of shrub and tree seeds, using temporary summer help. More intriguing is the approach at LAC Bullfrog, where a gas-powered leaf blower has been converted to a vacuum. The reclamation people run it up and down rocky washes where there is a good mix of native species growing and suck up whatever mix collects in the rocks. "We get a lot of seed that way. We got a whole bag of bursage in 1.5 hours that would have cost us $51 per pound commercially. We've collected Goldenhead, Macaranthera, and other stuff."

At a recent SCS plant materials meeting in Reno, the BLM's Jim McLaughlin described the "Native vs. Introduced Plants Policy for the BLM in 1992". "In the 1950s and 60s the BLM here seeded four million acres with crested wheatgrass. We are now trying to turn that around. Our current plan has one million acres [mostly cheatgrass] to convert to crested wheatgrass for livestock. Outside those areas, our intent is to maintain native perennials. In fire areas, if it's a wildlife area, we will do everything we can to get native perennials back. . . the policy will be to pursue plant diversity to the maximum. . ." When asked by SCS personnel about whether cultivars or other varieties of local natives would be acceptable, he indicated that in most cases they would be. "Monson and his crew have a lot of evidence that you can get native perennials established on mine sites." For now, the high cost and limited availability of local and native plant material is a stumbling block to its wider use, but increased demand for specific native species has traditionally led to greater supply, and

eventually more reasonable prices.

Threatened and Endangered Species

I'm not a total preservationist. If I was I'd have to commit suicide!" - Joel Mur, BLM Las Vegas

The issue of threatened and endangered species is also gaining more attention recently. Plants are more of a challenge in this respect on Nevada BLM deserts than animals. The desert tortoise can be kept out with fencing. More visible lately has been the goshawk, which when listed as a sensitive species by USFWS, incited the "goshawk" rebellion in eastern Nevada, with a group of non-miners lending their support to miners in emotional meetings organized by the Forest Service. "It's hell to have to try to manage something like that - it makes it nice to be here on the Carlin trend- an area where the resource values are relatively low!", said one BLM staffer there. Plants, by contrast, often attract less attention but are more likely to be difficult to preserve. (The goshawk issue was resolved at least temporarily by a moratorium on exploration drilling in areas where it nests, during the critical nesting period.) Most of the plant candidates and listed species for threatened or endangered status have very specific soil requirements, with little existing research available to determine exactly what criteria need to be met to propagate the plants. Where the soil is disturbed by mining, the situation becomes even more difficult.

Nevertheless, there are examples of mining activity in Nevada where sensitive plant species have been successfully transplanted and multiplied. The Crosby Buckwheat (Eriogonum crosbyae) on the Hog Ranch mine may be the best example. Here transplanted plugs are not only flourishing and spreading, but are showing over 1000 seedlings and new recruits throughout the area where they were planted. At Candelaria, the Candelaria Blazing Star (Mentzelia candelariae) and at First Miss Getchell the vetch (Astragalus yoder-williamsii) are viewed as much as opportunities to do something positive for the environment as they are obstacles to the mine's progress. Such an attitude may serve the mines well as more candidates for listing emerge. Several did in 1992, some of which, such as the Grimes Vetchling Lathyrus grimesii) and the Many-jointed Whipple Cholla (Opuntia whipplei multigeniculata) are endangered "by direct and indirect effects of mining". A mine which not only shows concern for such plants but investigates the possibility of cultivating them more widely than the naturally occur would probably accrue good will from the environmental press and public, and certainly from the USFWS.

Species Selection

"Everything fun happened on the afternoon of the third day- before that it was mainly darkness and light and afterward bureaucracy." - John McPhee

No factor in Nevada mine revegetation results in more stress and waste of time and money than the decision of what species to try. Only a few years ago such decisions were much easier - if there was more than eight inches of precipitation annually one planted crested wheat grass, if less, one planted nothing at all. As the section on native versus exotic species explains, things are much more complicated now. Site adaptation, species diversity, the encouragement of natural succession, and the goals of the reclamation effort must all be considered in the development of a seed mix for a given site.

In most cases, it is required that the goal of reclamation include a diverse plant community consisting of a mix of grasses, shrubs, and forbs. Since the goal is usually to 1) Support livestock grazing and 2) encourage wildlife, species which favor these two goals are those chosen. Only rarely is site stabilization mentioned as a primary goal in Nevada. In the case of mines which adjoin Death Valley National Monument near Beatty, the goal is to avoid the introduction of any alien genetic material, which is done by avoiding reseeding altogether. Nowhere did I encounter a situation where other objectives, such as visual resources or establishment of a historically native community were considered. However, it is still important to consider the desired goals and not merely what is easiest to grow in making up a species list for revegetation.

Responsibility for the creation of seed mixes is not established in Nevada. In most cases now, the BLM personnel in an area have the experience to suggest a mix, or to evaluate one suggested by a mine. As they gain experience through the reclamation permit process, the mines are also getting better at this. A typical process now is one such as was used at Hog Ranch - The mine proposed the first seed mix versions. The BLM range and wildlife personnel modified them. The mine then determined what similar mixes were commercially available and economically acceptable, and the BLM then approved that final version. Seed companies are not generally considered to be reliable sources of such information - "They are the worst people in existence for bad mouthing each other and they all know each other's horror stories" and because they naturally recommend what they personally are overstocked on and can make the most money from. Furthermore, since Nevada has no law against weeds in imported seed, (unless they are officially 'noxious'), the state is a great dumping ground for low quality seed. Thus it is important to specify seed quality in the contract, by specifying species name, percent of germination, percent pure live seed, percent weed seed and contaminants,

location of collection, and date of test. When certified seed is available, it is well worth the price for the uniformity and purity which it ensures. The SCS can assist with the determination of the range of acceptable characteristics for various species. Scientists may not always be the best sources of information for this either, since they tend to suggest expensive cultivars of many species which may be only marginally better while costing many times more per pound. As Newmont's Smithson says, "There are a lot of hybrids out there that will never be realistically affordable. A reclamation budget is just like a production budget - you have to justify every penny. It's fine for researchers to tell us what to plant, but if their hybrid costs an extra five dollars per pound and we come up $100,000 over budget, it will never happen!" Thus the BLM, which in many areas, such as Battle Mountain and Carson City districts has standard suggestions based on site elevation and precipitation, is probably the best source of information. The SCS also provides recommendations based on their experience in numerous test plots throughout the state's mining areas, although much of this information is too new and too subjective to be completely used. Simple test plots, involving numerous individual species or a "shotgun mix" of many possible species, still have the best potential for determining what will work on a given site. In general, the higher and wetter the site, the more species are likely to succeed. Thus a mine in the pinyon/juniper zone near Ely might use a mix of 15 species, all of which will thrive, while a mine near Candelaria will try five and be happy to get two of them up. The exception to this rule may be in extreme southern Nevada, where the typical Mojave flora is far more diverse than that which characterizes the higher and colder Great Basin or upper Sonoran zones.

The major determining factor in seed mixes is still cost and availability. Especially with the native seeds and newer introductions, supply and cost are highly variable. As I was told on the Battle Mountain district, "There are many good mixes on paper. Any resemblance between those and what is put in the ground is purely coincidental." Nor is the extensive experience of the Nevada DOT applicable in this case - their goals are completely different, since they don't want to attract cows and wildlife to the highways. Their needs are also different, since they irrigate almost all of their plantings - at least while they are germinating in remote areas and by permanent drip for ornamental species. And their environment is different - the roadsides get more run-off, more traffic, and more fumes, grit, and pollution.

Forbs are typically the hardest plants to establish, especially in the drier areas, where they are also less common in natural communities. They are also among the most expensive to plant, but with careful observation of adjacent undisturbed vegetation and the use of test plots, they can probably be established in almost any zone. Forage Kochia, while non-native, shows especial promise in dry and rocky areas. The attached appendix gives seed lists for various areas and conditions of the state which are based on my observations, but there are several species that deserve mention

here for their undesirability. Alfalfa is very often specified in mixes, especially in grass-dominated combinations and in northern Nevada. Yet almost all the BLM people I've talked to admit that although it comes up readily, it is immediately munched into oblivion and shows no persistence in any situation. My experience confirms this - although I have frequently seen seedlings of it where it has been planted, in two seasons of touring revegetated sites, I can't recall ever seeing an alfalfa plant consisting of more than one 6 inch sprig. Yet it continues to be included in many mixes "Because it makes the range people happy to see it there. With the seed so cheap, it seems a shame not to give them a smile by including it!" (Rodney Hannon, BLM Battle Mountain) Yarrow, while it occurs naturally in Nevada, is very rarely seen where it has been seeded. Others are cereal rye and yellow sweet clover, both popular because they do come up when planted. However, as Dr. Young points out, they are serious competitors with other plants for available water, and "they attract every rodent known to man." Yellow sweet clover is also a non-native and tends to disappear after the first biennial flush in two years. Furthermore, as Greytak of the NDF shrub nursery points out, "It really doesn't really have good forage value - it wouldn't be a five foot tall dead fire hazard everywhere if it did!" Wyoming sagebrush is also frequently used instead of more local basin big sagebrushes. According to Dr. Young, this is probably because it is assumed that its northern origins will ensure hardiness here. Yet it is the most expensive and the hardest to grow - less desirable in every way for use in Nevada.

One problem is that the seed market, especially for natives, is demand-driven but with a long lag between demand and availability. Furthermore, until the supply is plentiful, the prices are too high to encourage a demand, but until there is a demand, regardless of price, supply and prices remain high. This is especially noticeable with the native grasses, such as squirreltail, galleta, and needle and thread, which would be widely used if they were more affordable, but also occurs with the forbs and shrubs. One answer to this problem would be to encourage the collection of native seed on-site. The NDF encourages this, but points out the problems with using unskilled labor such as Boy Scouts, school groups and inmates, and the uncertainty of supply and quality. Nevertheless, this has been done successfully by several mines, especially with such easily handled shrubs as fourwing and winterfat, and with tree seeds. At LAC Bullfrog, the reveg personnel have been collecting native seed mixes by using backpack vacuums along rocky washes, which has been very successful. (See section on Natives) This technique has been used by them on bursage, goldenhead, panamint daisy, and other species. In addition to resolving the issue of climatic adaptation, it also avoids the introduction of new species, or even new genetic material in species already present. There are obviously hundreds of species with reclamation potential that are as yet unstudied. A few of these are mentioned in the section on research needs. Observation of undisturbed areas adjacent to mines will reveal others.

Another goal, rarely mentioned now in reclamation, but becoming more important as environmental concerns increase, is the fostering of succession on disturbed sites. This requires very different choices from those cases where the goal is to create an instant stable community such as fully stocked crested wheat, with no ecological opportunities for easy change of composition. There is always now the difficulty of choosing between a seed mix that will reliably give quick results (and quick bond release), and one that includes diversity and is likely to lead to a mature natural community. As Greytak says, "It's a tough call to put in enough grasses to stabilize the site and still leave some openings." In many cases, though, such grasses as crested wheat and smooth brome which slow secondary succession are being included in much smaller proportions in mixes. This is further discussed in the section on research needs.

Wildlife considerations are considered in other sections of this report, but it has been noted in studies in Nevada that bird species diversity increases along with complexity of the plant community, and that when sage communities are converted to monoculture grasses, bird diversity decreases. Many of the shrubs and forbs are also very important food sources for wildlife, and are thus justified in mixes even when they add substantially to the cost.

Seed List Suggestions

Flax ain't phlox ain't flacks ain't flocks!

The bottom line for every revegetation attempt is the list of species in the seed mix to be planted. In general, success is most likely with a minimum number of simple mixes that include the three basic reveg groups, grasses, forbs, and shrubs. While some mines, such as Independence, which have an extensive and biologically trained reclamation department, may have a seed mix tailored to every minor variation on their project (Independence uses 40 different mixes now!), most would be happy to have one mix, or maybe a couple, that will perform reliably under the various conditions at the mine.

The following seed mix suggestions are derived from USFS lists, BLM lists, mine lists, and my observations combined.

On the Ely District, seedmixes for the wetter areas often include more species variety than mixes for drier areas on other districts. Typical of these is the mix used on waste dumps at Placer Dome's Bald Mountain mine. The dumps were topsoiled and covered with slash from the pinyon/juniper forest which extended down over parts of the minesite before mining activity. The mix included Hycrest wheatgrass, Magnar Great Basin wildrye, Critana thickspike wheatgrass, Nezpa Indian ricegrass, Remont sainfoin, Ladak alfafa, Madrid yellow sweetclover, Delar small burnet, Appar blue flax, Cedar Palmer penstemon, forage Kochia (also known as Emigrant or prostate Kochia), fourwing saltbush, and bitterbrush, all broadcast seeded and dragged. Despite heavy rodent/rabbit predation on this very palatable combination, all 13 species were observed flourishing in dense stands over the whole site. This was especially remarkable because of the high concentration of forbs, generally assumed to be the hardest component of a mix to get established. This seeding was probably the single most successful and diverse revegetation effort which I observed in the course of this project. Other simpler mixes at this mine, which included Hycrest crested wheatgrass, Vinall Russian wildrye, Critana thickspike wheatgrass, Nespar Indian ricegrass, fourwing saltbush, and yellow sweet clover, were heavily dominated initially by the clover. There was good fourwing in the clover though, with many grass seedlings (unidentified) struggling amid the tall clover.

Other sites in the Ely area, such as Illipah and many notice-level disturbances, used simpler mixes. At Illipah, this consisted of Fairway crested wheatgrass, small burnet, Russian wildrye, yellow sweetclover, and bluebunch wheatgrass. Unfortunately, cattle had destroyed most of the vegetation at these unfenced locations, so that it was not possible to determine how the mixes might have succeeded with some protection from grazing. Grazing has also

affected the tests at Casino. Here a wide variety of grasses were tried in various combinations, along with Kochia, yellow sweetclover, sainfoin, burnet, penstemon, yarrow, alfalfa, white sweetclover, sulfur buckwheat and flax. In some areas, surface compaction and crusting resulted in failure, and in the others cattle and horses wiped out most of the vegetation. The surviving plants were mostly clover, sainfoin, rye, and crested wheatgrass.

If a goal of revegetation in the Ely area was ever determined to be visual attractiveness, an aesthetically pleasing mix of plants naturally occurring in the area might include yellow and purple Cleomella (Bee plant), annual sunflower, white prickly poppy (Argemone) Mentzelia, one of the several purple asters, and Prince's plume (Stanleya).

On the Battle Mountain District:

At the Beacon Hill pit a test plot established some years ago provides the closest thing available to a study of longer-term persistence of revegetation species in central Nevada. The list of known survivors from Beacon Hill includes:

Spiny Hopsage
Lewis Flax
Palmer Penstemon
Nevada Ephedra
Kochia
Winterfat (Pamirian)
Fourwing saltbush
Globe Mallow
Prince's Plume
Wyethia
Big Sagebrush
Little Rabbitbrush
Basin wildrye
Crested wheatgrass
Horse brush
Budsage
Sandberg Bluegrass

Battle Mountain has compiled a standard list of seed mixes based on the various elevations and precipitation levels encountered on the district. For dry slopes and valley floors between 4000 and 6000 feet, the following are suggested:

Crested wheatgrass	2 lbs/acre
Basin wildrye	2 lbs/acre
Bottlebrush squirreltail	1 lb/acre
Indian Ricegrass	1 lb/acre
Ladak alfalfa	2 lbs/acre
Fourwing saltbush	2 lbs/acre
Shadscale	2 lbs/acre

Total = 12 lbs/acre by drill, double rate for broadcast. They recommend that 5 of these 7 be seeded, including forb and shrubs.

affected the tests at Casino. Here a wide variety of grasses were tried in various combinations, along with Nootka, yellow sweetclover, saltgrass, Durnet, penstemon, yarrow, alfalfa, white sweetclover, sulfur buckwheat and flax. In some areas, surface compaction and crusting resulted in failure, and in the others cattle and horses wiped out most of the vegetation. The surviving plants were mostly clover, saltgrass, rye, and crested wheatgrass.

If a goal of revegetation in the Sly area was ever determined to be visual attractiveness, an aesthetically pleasing mix of plants naturally occurring in the area might include yellow and purple Clarkia (bee plant), annual sunflower, white prickly poppy (Argemone) Mentzelia, one of the several purple asters, and Prince's plume (Stanleya).

On the Battle Mountain District:

At the Beacon Hill pit a test plot established some years ago provides the closest thing available to a study of longer-term persistence of revegetation species in central Nevada. The list of known survivors from Beacon Hill includes:

Shiny Hopsage
Lewis Flax
Palmer Penstemon
Nevada Ephedra
Kochia
Winterfat (Pearlian)
Fourwing saltbush
Globe Mallow
Prince's Plume
Myerbia
Big Sagebrush
Little Rabbitbrush
Basin wildrye
Crested wheatgrass
Horse brush
Budsage
Sandberg Bluegrass

Battle Mountain has compiled a standard list of seed mixes based on the various elevations and precipitation levels encountered on the district. For dry slope and valley floors between 4000 and 6000 feet, the following are suggested:

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Basin wildrye	2 lbs/acre
Bottlebrush squirreltail	1 lb/acre
Indian Ricegrass	1 lb/acre
Lewis alfalfa	2 lbs/acre
Fourwing saltbush	2 lbs/acre
Shadscale	2 lbs/acre

Total = 12 lbs/acre by drill, double rate for broadcast. They recommend that 5 of these 7 be seeded, including forb and shrubs.

Ricegrass is more adapted to sandy sites. Shadscale often invades naturally with better success than by seeding.

For elevations between 5500 and 7500 feet, with the same stipulations as above:

Indian Ricegrass	2 lbs/acre
Pubescent wheatgrass	2 lbs/acre
Western wheatgrass	1 lb/acre
Needle and thread grass	1/2 lb acre
Basin wildrye	2 lbs/acre
Bottlebrush squirreltail	1 lb/acre
Fourwing saltbush	1 lb/acre
Small burnet	1/2 lb/acre
Sainfoin	1/2 lb/acre
Ladak alfalfa	2 lbs/acre
Total	10.5 lbs/acre

For moist sites between 7000 and 8000 feet:

Western wheatgrass	1 lb/acre
Thickspike wheatgrass	2 lbs/acre
Basin wildrye	4 lbs/acre
Indian ricegrass	2 lbs/acre
Bluebunch wheatgrass	1 lb/acre
Idaho fescue	1 lb/acre
Bitterbrush	2 lbs/acre
Small burnet	1 lb/acre
Blue flax	1 lb/acre
Ladak alfalfa	4 lbs/acre
Utah sweetclover	1 lb/acre
Cicer milkvetch	1 lb/acre
Lupine	1 lb/acre
Total	22 lbs/acre (Double if broadcast)

Recommend 9 of 13 species, including forbs, grasses, and shrubs.

For wildlife-sensitive areas with 10 inches rainfall or less:

Bluebunch wheatgrass	2 lbs/acre
Indian ricegrass (sandy areas)	1 lb/acre
Basin wildrye	2 lbs/acre
Ladak alfalfa	3 lbs/acre
Utah sweetvetch	1 lb/acre
Small burnet	1 lb/acre
Fourwing saltbush	2 lbs/acre
Winterfat	1 lb/acre
Total	11 lbs/acre (double if broadcast)

Recommend 6 of 8 species, including forbs, grasses, shrubs.

For wildlife sensitive areas with 12 inches rainfall or more:

Bluebunch wheatgrass	1 lb/acre
Idaho fescue	1 lb/acre
Indian ricegrass (sandy areas)	1 lb/acre

Ricegrass is more adapted to sandy sites. Shadescale often invades naturally with better success than by seeding.

For elevations between 6500 and 7500 feet, with the same stipulations as above:

Indian Ricegrass	2 lbs/acre
Pubescent wheatgrass	2 lbs/acre
Western wheatgrass	1 lb/acre
Needle and thread grass	1/2 lb acre
Basin wildrye	2 lbs/acre
Bottlebrush squirreltail	1 lb/acre
Pourving saltbush	1 lb/acre
Small burnet	1/2 lb/acre
Sainfoin	1/2 lb/acre
Ladak alfalfa	2 lbs/acre
Total	10.0 lbs/acre

For moist sites between 7000 and 8000 feet:

Western wheatgrass	1 lb/acre
Thickspike wheatgrass	2 lbs/acre
Basin wildrye	4 lbs/acre
Indian ricegrass	2 lbs/acre
Bluebunch wheatgrass	1 lb/acre
Idaho fescue	1 lb/acre
Bitterbrush	2 lbs/acre
Small burnet	1 lb/acre
Blue flax	1 lb/acre
Ladak alfalfa	4 lbs/acre
Utah sweetclover	1 lb/acre
Clear milkvetch	1 lb/acre
Lupine	1 lb/acre
Total	22 lbs/acre (Double if broadcast)

Recommend 9 of 13 species, including forbs, grasses, and shrubs.

For wildlife-sensitive areas with 10 inches rainfall or less:

Bluebunch wheatgrass	2 lbs/acre
Indian ricegrass (sandy areas)	1 lb/acre
Basin wildrye	2 lbs/acre
Ladak alfalfa	2 lbs/acre
Utah sweetvetch	1 lb/acre
Small burnet	1 lb/acre
Pourving saltbush	2 lbs/acre
Winterfat	1 lb/acre
Total	11 lbs/acre (double if broadcast)

Recommend 6 of 8 species, including forbs, grasses, shrubs.

For wildlife sensitive areas with 12 inches rainfall or more:

Bluebunch wheatgrass	1 lb/acre
Idaho fescue	1 lb/acre
Indian ricegrass (sandy areas)	1 lb/acre

Basin wildrye	2 lbs/acre
Ladak alfalfa	2 lbs acre
Small burnet	1 lb/acre
Cicer milkvetch	1/2 lb/acre
Blue flax	1 lb/acre
Lupine	1/2 lb/acre
Bitterbrush	2 lbs/acre
Mt. Mahogany(steep, limey upland	1/2 lb/acre
Total	10.5 lbs/acre, (double if broadcast)

Recommend 9 of 11 species, including forbs, shrubs, grasses.\

Other seedmixes on the district include Echo Bay's:
Ephedra
Ladak alfalfa
Fourwing saltbush
Crested wheat grass
Siberian wheatgrass
Small burnet

At McCoy Cove, all of these did well except the burnet. Echo Bay has used several other seed mixes here, including wheatex wheatgrass, sand dropseed, penstemon, alkali sacaton, western wheatgrass, Siberian wheatgrass, and rabbitbrush. The combination of the drought and the lack of adequate marking of test plots made it impossible to evaluate the success of most of these trial species. Elsewhere on the district, Lynn Petit has observed that the Basin wildrye does well in a wide variety of situations. The district has also begun recommending rabbitbrush for cover and stability "So we have changed our tune on rabbitbrush, but only on waste dumps!" Winterfat could probably be more widely included in the mixes for drier areas, since it has done well even in extremely dry areas to the south and west.

On the Elko district, I was not able to obtain seed mix lists from Newmont, but observed good grass, mallow, and fourwing on the non-topsoiled waste dump site. At Barrick, numerous mixes have been tried. Three examples from the tailings embankment are 1. The 'all-around' mix: Intermediate wheatgrass, Great Basin Wildrye, bluebunch wheatgrass, Indian ricegrass, Yellow sweetclover, fourwing saltbush, bitterbrush, and small burnet. 2. The "BLM" mix contains bluebunch wheatgrass, Great Basin wildrye, western wheatgrass, pubescent wheatgrass, thickspike wheatgrass, prostrate kochia, Lewis flax, and fourwing saltbush. 3. An overseeding mix of Wyoming sagebrush, emigrant kochia, and white stem rubber rabbitbrush. Among the most successful by my observation were the fourwing, burnet, clover, the grasses, and Kochia. On the angle of repose slopes along the access road the burnet and crested wheatgrass were well established despite cattle grazing. Independence, which has had up to 47 different mixes at times, which include Great Basin wildrye, streambank and intermediate wheatgrasses, smooth brome, penstemon, Idaho fescue, burnet, flax, Ladak alfalfa, bitterbrush and sagebrush. Here again the grasses, burnet, and clover stood out, with some bitterbrush and penstemon. At Buckhorn mine, Cominco has three basic mixes. The dump seed mix

includes intermediate wheatgrass, beardless bluebunch wheatgrass, green needlegrass, sheep fescue, Great Basin wildrye, small burnet, yellow sweet clover, Ladak alfalfa, gray rabbitbrush, and fourwing saltbush. The most successful here by observation were the fourwing, burnet, clover, and the grasses, especially the wheatgrasses and Great Basin wildrye. The streambank mix includes beardless wild rye, Canadian bluegrass, streambank wheatgrass, thickspike wheatgrass, smooth brome, yellow sweet clover, Ladak alfalfa, sainfoin, burnet, fourwing saltbush, and gray rabbitbrush. The drill road mix has intermediate wheatgrass, streambank wheatgrass, Great Basin wildrye, burnet, yellow sweet clover, and Ladak alfalfa.

On Winnemucca district the best successes have been with fourwing saltbush, crested wheatgrass (where there is sufficient precip), alfalfa, Palmer penstemon, Appar flax, shadscale, and forage kochia. Winterfat is also very successful in some areas, though is not always widely used due to the rocky surfaces. "We recommend that the source of the seed be northern Nevada or Utah or the Snake river plains. Anything from south of us just doesn't work here." At Pinson, burnet is considered to be a consistent failure. Pinson uses a variety of mixes, including the following: Fairway crested wheatgrass, fourwing, forage kochia, Nevada ephedra, yellow sweet clover, wyoming sage, Palmer penstemon, siberian wheatgrass, shadscale, globemallow, Nezpar Indian ricegrass, sand dropseed, other thickspike and crested wheatgrasses, rubber rabbitbrush, Lewis flax, bitterbrush, and Great Basin wildrye. At Getchell, the mix includes Ephraim crested wheatgrass, Great Basin wildrye, Sodar stream wheatgrass, Indian ricegrass, squirreltail, fourwing, Sandberg bluegrass, Lewis flax, Palmer penstemon, rabbitbrush, and Lupine (Alpestris). At Winnemucca Mountain (Santa Fe) the mix includes Nordan Crested wheatgrass, fourwing, shadscale, perennial ryegrass, Ladak alfalfa, and Indian ricegrass. At Cosgrave a quarry bench seed mix included Lewis flax, bitterbrush, Indian ricegrass, Great Basin wildrye, fourwing, blueleaf aster, and thickspike wheatgrass. For the plant site, the mix was Indian ricegrass, bottlebrush squirreltail, Nordan crested wheatgrass, winterfat, shadscale, globemallow, and Utah Sweetvetch.

Even in areas on the Carson and Tonopah districts, where it is frequently assumed to be to dry to try seeding, several mines have had success with broadcast seeding.
At Candelaria, only two mixes were tried. One was Galleta with Douglas rabbitbrush, the other was Kochia, shadscale, Nevada ephedra, and bottlebrush squirreltail. Ephedra and Kochia did well, while shadscale and Galleta grass were successful in some spots.

At the Santa Fe mine near Gabbs, seed mixes included the following species at various concentrations: Indian ricegrass, bottlebrush squirreltail, tall wheatgrass, crested wheatgrass, Siberian wheatgrass, streambank wheatgrass, annual sunflower, Russian wildrye, shadscale, fourwing saltbush, and Nevada ephedra. The

components were the same for the various sites, including gentle slopes, reclaimed heaps, and waste rock dumps, although the percentages varied by use. Although severe drought and heavy summer storm erosion had been problems in the preceding year, Indian ricegrass, wheatgrass, fourwing, and ephedra were abundant in some flatter areas.

In one of the wettest BLM mine sites in the state, at Cerro Duro in the Wassuk range, Echo Bay's mix for roads and pads included crested wheatgrass, Siberian wheatgrass, Lewis flax, Nevada ephedra, and fourwing saltbush. For dumps, the mix included Palmer penstemon, white yarrow, and fourwing. Only a few yarrow were noted, which has been the case in other areas where it has been seeded. The other species did extremely well in some patches, while immediately adjacent areas were strikingly barren. This is discussed further in the section on soil analysis. A lack of suitable microsites for germination on the slopes may also have been a factor here.

At Grefco, the Kochia, fourwing, Indian ricegrass, shadscale, and winterfat were quite successful, while the sage, alfalfa, and yellow sweet clover were failures. The wheatgrasses were only slightly successful. The biggest successes here were the winterfat and kochia, and the invading rabbitbrush, shadscale, ephedra, fourwing, and Stanleya.

Round Mountain's mix includes white yarrow, desert globemallow, canby bluegrass, bottlebrush squirreltail, crested wheatgrass, galleta, Indian ricegrass, Basin wildrye, streambank wheatgrass, thickspike wheatgrass, shadscale, and fourwing saltbush. The grasses, atriplexes and bursage were generally successful.

At LAC Bullfrog, another very dry site, one typical mix included Globemallow, Atriplex polycarpa, Plantago usilaris, P. patagonica, white bursage, and trough-leaf bursage. Grasses, atriplexes, and bursages have been successful here, while the globemallow and plantagos were not. Unseeded areas of the tailings dam also showed good invasion of shadscale, annual buckwheats, bursages, and Stephanomeria.

Nevertheless, a vegetation management paper from the Tonopah office suggests only topsoil replacement and perhaps transplanting of shrubs for areas in the 3 to 5 inch precip zone. In the 5 to 8 inch zones, for linear disturbances, Indian ricegrass and fourwing are suggested. For larger areas, recommended species for seeding include those two plus bottlebrush squirreltail, rubber rabbitbrush, and shadscale. My observations suggest that both rabbitbrush and shadscale are difficult to establish by seeding, and are very likely to spontaneously invade disturbed areas in the Tonopah area. For the sagebrush zone, with 8 to 12 inches of precip, the recommendations include crested wheatgrass, Basin wildrye, Lewis flax, Kochia, Mexican cliffrose, desert bitterbrush, black sagebrush, and Wyoming big sagebrush. I did not observe any seedings in that zone in the Tonopah area. Elsewhere in this

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At Cretes, the Rocks, fourwing, Indian ricegrass, ephedra, and wintefat were quite successful, while the sage, alkali, and yellow sweet clover were failures. The wheatgrasses were only slightly successful. The biggest successes here were the wintefat and kochia, and the investing rabbitbrush, ephedra, ephedra, fourwing, and Stanley.

Round Mountain's mix included white yarrow, desert globemallow, canby bluegrass, bottlebrush squirreltail, crested wheatgrass, gailia, Indian ricegrass, Basin wildrye, streambank wheatgrass, Chikopsis wheatgrass, ephedra, and fourwing saltbush. The grasses, stripleaves and borages were generally successful.

At LAC Butting, another very dry site, one typical mix included Globemallow, Stipiba nelsonna, Elantana nellaria, P. petiolata, white burrage, and Cryptp-leaf borrage. Grasses, stripleaves, and burrages have been successful here, while the globemallow and plantages were not. Seeded areas of the Cutting dam also showed good invasion of ephedra, annual bucknowats, burrages, and Schoonmarcia.

Heavyplains, a vegetation management paper from the Tonopah office suggests only topsoil replacement and perhaps transplanting of shrubs for areas in the 3 to 6 inch precip zone. In the 6 to 8 inch zones, for linear disturbance, Indian ricegrass and fourwing are suggested. For larger areas, recommended species for seeding include those, two pins bottlebrush squirreltail, rubber rabbitbrush, and ephedra. My observations suggest that both rabbitbrush and ephedra are difficult to establish by seeding and are very likely to experimentally invade disturbed areas in the Tonopah area. For the sagebrush zone, with 8 to 12 inches of precip, the recommendations include crested wheatgrass, Basin wildrye, Lewis flax, kochia, Western wildrye, desert bittebrush, black sagebrush, and Wyoming big sagebrush. I did not observe any seedings in that zone in the Tonopah area. Elsewhere in this

report the difficulties of seeding bitterbrush and sagebrush are discussed.

Region 4 of the US Forest Service has a very extensive list of recommended species, broken down by areas which include the salt desert shrub zone with 6 to 10 inches of precipitation, sagebrush-foothill areas with 10 to 13 inches precip, and sagebrush-pinyon/juniper - mountainbrush areas with 13 to 18 inches. While these lists are too long to include here, they may be very useful to managers dealing with the wetter areas of BLM lands in Nevada. The list for the salt desert shrub areas is essentially the same as the lists which the BLM already follows for such areas.

The Las Vegas area is another one which is frequently said to be too dry to seed, but where several revegetation attempts have been quite successful. One such attempt was on the Kern River pipeline. A short stretch of the disturbed right of way was seeded in 1991 with a mix that included Indian ricegrass, small burnet, globe mallow, palmer penstemon, Nevada ephedra, and winterfat. Despite the crusted and rocky surface and the lack of topsoil, the vegetation one year later was spectacularly successful. Most obvious were the winterfat, penstemon, and mallow, which combined to nearly cover the surface in some spots. At Colorock quarry, an oilwell test drill site, in addition to successful transplanting discussed elsewhere, was seeded with a mix of 7 lbs. Galleta, 7 lbs. Indian ricegrass, and five lbs. fourwing saltbush. Despite very low precip, even by local standards, the fourwing was very successful and some grasses were apparent.

Several species deserve additional comment, either for their potential or for difficulties involved with their use in seed mixes. Winterfat seems to do very well on rocky and powdery sites throughout the state. It also appears to spread rapidly once established. Globemallow, which is gaining increasing attention for its forage value, is highly variable in emergence. While it readily sprouts in some sites, such as Newmont, from seedings, and emerges spontaneously in other disturbed areas such as Candelaria, it fails to emerge in many apparently good locations where it has been included in the seed mix. It is probably worth adding to seed mixes, at least for testing, throughout the salt shrub and southern desert areas, but it would be interesting to know why its success has so far been so unpredictable. Bitterbrush has a reputation for doing poorly when included in mixes, although it has been observed doing very well in several areas where it was included in mixes. Greytak at the NDF shrub nursery suggests that in many areas, especially in eastern Nevada, Cowania (cliffrose) might be more appropriate than bitterbrush. For test purposes, at least, it might be worthwhile to try it both in mixes and by itself, though. Sagebrush, frequently included in mixes, should actually be overseeded after drilling or dragging of the surface. Other factors are discussed in the sections on seeding methods and equipment, and on further research needs.

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Seeding Timing, Equipment, and Methods

"Is it too late to plant this year? Well, an old rancher told me that he has never seen it start in the sack!"
- Dr. J. Young

The time of seeding efforts is one of the least controversial aspects of Nevada mine reclamation. Nearly everyone agrees that the best time is just a few minutes before the fall storms start. This opinion is shared by the state, the BLM, and the miners themselves. At Barrick, Gary Goodrich says "We are real believers in fall seeding - October, November, and December. Sometimes the guys are out there fighting blizzards. It's a headache but it works." Early spring seedings are done when the timing is too late for fall, but are generally not as successful. Winnemucca district prefers October and November, while Ely feels that the span from October 1 to March 30 is acceptable. Certainly late spring and summer seedings are usually a waste of time and material except where irrigation is practiced. There have been some successes with overseeding onto snow in heavy snowfall areas, though bird and rodent predation probably consumes much of this seed.

The actually method of planting is not usually as important as good preparation of the seed bed. This is discussed in its own section of this report and cannot be over emphasized. No combination of seed and planting technique can make up for a surface that is too smooth or too crusted to provide good seed germination sites. As with most other factors, there is nothing like a good test site to evaluate seeding methods and the equipment, but much of this will be dictated by what is available and the slope and roughness of the area being seeded.

Drill seeding is the preferred method where surfaces don't include too many big rocks and are accessible to heavy equipment. This rules out slopes much steeper than four to one, or in some cases three to one, as well as smaller and rocky sites. Rangeland drills are not widely available, but are built to handle the rougher surfaces much better than traditional seed drills. Not only are row crop drills too fragile in this application, but where they have been used, such as at Round Mountain, there have been problems with crimping of the rubber hoses at the bottom of the seed tubes. This was resolved by removing those hoses, but that has the effect of turning the whole machine into a ponderous low altitude broadcast seeder instead of a drill. Contrary to rumors about the demise of the Rangeland drill manufacturers, they are still available through Miller Grass Seed company at Box 81823, Lincoln, NE 68501 or through Laird Welding, P.O. Box 1053, Merced, CA. 95340 (209) 722 4145, and cost about $15,000. These drills also require careful calibration of the seeding rate, careful depth setting, and agitation of the seed mix to make sure that the denser material does not sink to the bottom of the seed box. They can be set up with separate boxes to include denser seeds in their own rows, though. There are various seeds that don't work well in drills for other reasons too, such as fluffy seeds or awned grasses

which plug the seed tubes, or sagebrush, which must be placed on top of the seedbed and compacted, not drilled into it. Seed rates recommended by Winnemucca for drilling are about 20 to 40 seeds per square meter.

Broadcast seeding is the most commonly used seeding method on Nevada minesites by far. It is also the easiest, requires the least special equipment, and can be arranged to allow for efficient reclamation in terms of reducing the number of passes which equipment must make. An example of this simplicity, which has been practiced in many areas, is to scarify the seedbed after topsoiling with grader rippers, which are shallow, and then drag a piece of chain link fence weighted with tires behind a pickup which is carrying a couple of guys leaning out and cranking hand operated broadcast seeders, popularly known as whirlybirds or bellygrinders. While calibration of seed application rate is a challenge, and the seeding rate usually needs to be double that of drill seeding, this is a very cheap and rapid way to do the job and usually gives great results. The seed rates, which again can be modified based on test plot results, are specified at about 40 to 80 seeds per square meter by Winnemucca district. Some fluffy seeds, such as bursage and creosote bush, are also difficult to distribute from broadcasters as well as drills. On the ground calibration is done on some mines, such as Pinson, simply by marking off a test area of known size and going onto it with a known amount of seed until the rate is adjusted up or down to the specification. Broadcast seeders can also be mounted on most wheel or crawler type tractors, and are PTO or hydraulically driven. This allows for very efficient and successful seeding, because the seeder can be mounted on either the front or back, with the rake or drag behind. Dragging or raking in is an absolute necessity for all broadcast seeding anywhere in the state- failure to do so is a frequent cause of failure. No special gear is needed, in fact, where it has been used it may not work as well as something cobbled up out of scrap. At Hog Ranch, for example, where a spring harrow is used, tractor rear windows are routinely smashed by rocks which catch a spring tooth and are vaulted up and out of the ground. One of the best pieces of equipment on which to base seeders and drags is the Cat Challenger. The rubber tracks require some attention on the rocky surfaces typical of mine dumps, but the lack of compaction, the high ground speed and maneuverability, and the cleat prints all combine to leave a seeded surface in near-ideal condition for germination with little time spent on it. These tractors have been used with broadcast seeders at Borealis and McCoy Cove, among other places, with excellent success. Low ground pressure or LGP cats, which have wide metal tracks, are also being used successfully in several places, including Barrick, where they are used to imprint cleat marks onto slopes before the slopes are hydroseeded. The success of this technique is obvious- almost all of the vegetation on these slopes has emerged in those cleat prints. All such tracked vehicles are much faster and more stable, thus safer, on the rough, uneven, and steep slopes typical of the mines than are standard farm tractors. Miners have also found ways to attach shallow rippers to such tractors in order to add that step onto the

same pass as seeding and dragging. Although somewhat labor-intensive, hand crews with landscaping rakes have also been used to cover broadcast seed, according to John McLain, who feels that a good crew working downslope can provide excellent results at an acceptable cost.

A prototype ripper-seeder developed by Taylor Implements attaches to cats and has been used on exploration roads on the Winnemucca district, where it greatly impressed BLM personnel for its ability to handle up to 40% slopes. Unfortunately it is not yet on the market. Dr. Young has pointed out that the old Model B contour furrower would also work well in such situations, and wonders if any are still in existence.

Good soil contact is essential for many seeds, regardless of the planting method, though. This is one of the main problems with the various hydroseeding techniques. The Nevada DOT uses hydroseeding extensively, but they have the resources and access to allow subsequent irrigation, and far fewer constraints about what species they use. In most cases, hydroseeding has been a total failure on mine sites in the state, and almost all BLM personnel mention it first when asked about things that never work. Yet Newmont has had some success with it on rough, steep slopes, especially with grasses. Barrick relies on it very extensively for a wide variety of species with very good success, at least initially. Although everyone is waiting to see if later survival maintains the initial germination success, it seems that their two step process, done by contractor WRR, has so far worked very well. In this process, the seed is put down with about 500 pounds per acre of the mulch (wood fiber, oat residue, or pelletized alfalfa) in the first step, which is soon followed by a second step in which the remaining 1000 to 1500 pounds of mulch and the fertilizer is applied. This may account for their success, since it probably reduces the main complaints about hydromulching in the desert. These are that the seed ends up suspended above the soil surface in the mulch, and that the moisture is wicked away from the seed root and into the atmosphere by the mulch. Barrick had also planned to test on their steep slopes a device manufactured by the Highway Equipment Company, the airsoiler, which may be used to blow on topsoil along with the seed, mulch, and fertilizer, so that the seeding operation occurs all in one step. This would result in considerable savings in labor, since Barrick estimates that their own topsoil still costs them at least $2 per yard to redistribute now. However, this equipment did not become available.

Numerous other types of equipment have been developed for drill seeding, punch seeding, dribble seeding, soil imprinting, containerized seedling transplanting, steep slope work, seed collection, clump transplanting, and other chores, but few appear to have gone beyond the prototype stage, and except for the steep-slope devices, they don't appear to address any problems faced by Nevada mines better than the standard equipment described above and in the transplant section.

Transplanting of shrubs and trees

Shrubs pose a greater challenge to mine revegetation efforts in Nevada than do grasses and forbs, but are a crucial component in most stable plant communities here. As the BLM Surface Management Manual points out, even a few shrubs will serve as a seed source for further establishment. But most revegetation plans stipulate a shrub component in the revegetated areas, and thus it is important for mines to be able to get them established quickly and reliably.

By far the most common method of establishing shrubs on disturbed lands in Nevada is, like grasses and forbs, by seeding. This is discussed in the section on seed selection. But there are a number of other options, mostly more expensive, but also more reliable and quicker. The easiest and cheapest is to avoid deep scraping of the land where possible, so that shrubs such as rabbitbrush, ephedra, and creosote bush can resprout from the roots. Obviously this is rarely possible except on exploration roads and some drill pads, but where it is feasible it results in rapid and free shrub regeneration. In most situations, some form of transplanting is the only alternative to seeding. Although many ways to transplant have been developed for arid areas, few mines have done much of it, due to the cost of materials and labor. Among the exceptions are Independence near Elko and LAC-Bullfrog near Rhyolite.

Although a number of shrubs have been propagated experimentally in Nevada by rooting of stem cuttings, by far the most accepted method of generating transplant stock is by growing it out from seed. This is a generally very reliable method, which has been used by CalTrans in Mono and Inyo county for highway right-of-way revegetation and by many other entities both public and private. The ARS has conducted transplant experiments on Lahontan sands at Flanigan, one of the driest sites in the state, with good success for a number of species. One of the leading sources for both information and transplanting stock is the Nevada State Shrub Nursery, a division of the Nevada Division of Forestry, and located in Washoe Valley. They grow transplant stock from either their own seed, purchased seed, or seed supplied by the customer, on a contract basis which usually costs about 75 cents per tubeling. According to Pat Murphy at NDF, the major considerations in selecting species are drought tolerance, cold tolerance, and suitability for the site soil. Of course, collecting native seed from the general area where the transplanting will take place will usually deal with these considerations automatically.

Timing and advance planning are critical. The nursery recommends that the planting for transplants begin three years before their use is anticipated, in case of a seed failure. This also allows the seedlings to reach an adequate root volume (10 cubic inches for tubelings and 30 for quart containers). Prior to planting out, the

seedlings will need time to be acclimated. Then one must hit the "planting window" when it is open. NDF strongly advocates fertilization with a time release such as Osmocote, which adds only about five cents cost per plant. Actually planting requires careful planning. Often on sites with several aspects, one site will be ready to plant as another's window is closing. Usually this would mean planting the west face first, then south, then east, then north, although this needs to be adjusted individually for each site. Planting needs to take place carefully, whether from the bottom up or the top down. When such groups as Boy Scouts or prison inmates are used, careful supervision of this is essential, since one of the biggest factors in plant loss is burying by debris movement. Crew leaders point out that using such unskilled crews is "like trying to control a herd of sheep!" Where the soil is especially prone to movement, taller seedlings (12 inches or more) are needed to cope with the surface shifts while still maintaining good root/soil contact. Irrigation, at least at the time of planting, is often very useful, although longer term irrigation may actually reduce plant growth in some cases.

At the Independence mine about 1500 rose, chokecherry, and elderberry plants were transplanted on the site with a tree spade, with about a 40% survival rate. 150 aspen similarly moved had a 40 to 50% survival with watering, and about 30% without. Mountain mahogany, snowberry, and serviceberry transplants had similar survival success, while rabbitbrush and bitterbrush did poorly. Great Basin Wild Rye survived 100%. The drawback to the use of the tree spade is that it costs about 20 to 50 dollars per clump, and of course one must have stock suitable for transplanting available near the site. Chokecherry seedlings transplanted by tubeling at the same site had 47% survival at a much lower cost. The NDF nursery is a greatly underused resource available to the mines of Nevada, and could, if used, help establish shrubs quickly and reliably at relatively low cost where seeding has not been successful. They offer information on planting technique as well as plant materials.

One interesting shrub transplanting took place in southern Nevada at the Colorock quarry test well site, where an oil drilling pad was revegetated by Boy Scouts on two Saturdays. The 450 shrubs used were salvaged from a Nevada DOT materials site, and consisted of burro brush, creosote bush, beavertail and cholla cacti, plus globe mallow. After seeding and transplanting, the site was watered three times weekly for six weeks. Seeding success for the Fourwing saltbush was good. Of the transplants, nearly all the cacti survived, along with about 70 to 80% of the burro brush, 60% of the creosote bush and 20% of the globemallow. This work was done in 1983 and the site is now so densely covered with shrubs that it was very difficult to locate on the ground nine years later. From the rock formations above it though, the exact outlines were very obvious as the saltbush stood out vividly among the surrounding duller vegetation.

Shrub transplanting is especially attractive in the arid areas of

southern Nevada, where seeding success is sometimes limited and natural invasion uncertain. Perhaps the most advanced method, which is being used by LAC minerals at their Bullfrog mine, was developed by the Center for Arid Lands Restoration at Joshua Tree National Monument. This "tall pot" or "deep pot" technique uses either cuttings or tubelings from seed. As practiced at Bullfrog, the seedlings are grown in rolls of newspaper (full width) until they are well established, then moved into PVC white plastic tubes, six inches in diameter and 30 inches long, with hardware cloth covering the bottom. The seedlings are greenhouse grown under drip irrigation until roots emerge from the bottom of the PVC tubes, then are transplanted into 30 inch deep, auger dug holes. Hay hooks are then used to yank out the PVC, so the plant hits the ground with a 30 inch root system in place. With one watering at time of transplant, the success rate is about 80%. Although this is obviously not a cheap system, LAC plans to use it to establish islands of vegetation on their dumps, from which it is hoped natural vegetation will spread. NDF estimates that such stock could be produced by them for about nine dollars each. Although the researchers at Joshua Tree are just now beginning a two year project to look at mine reveg, in cooperation with the Bureau of Mines, LAC has successfully used the method with Fourwing saltbush, Ephedra, bur sage, joshua trees, goldenhead, desert asters, and spiny menodora. A simpler version of the same technique, developed by Bainbridge in San Diego, uses 16 inch cardboard tubelings, for which he claims a 90% average survival with one watering. Another similar system is being developed overseas. This European Tubex project is also cheaper, and has been used there where winterkill, vandalism, and rodents have been problems.

Whatever the specific method, shrub transplanting has been underused as a means of establishing this important component of the plant community on difficult or "slow" arid sites and should be further explored where seeding has not been successful.

Predation

Not even prolonged drought is as severe a threat to an otherwise successful revegetation effort as animal predation. In many areas of Nevada, jackrabbits and smaller rodents have wiped out both seedlings and mature plants on revegetated mine sites. Rabbit-proof fences have been erected at Cominco's test plots and other sites, but are almost always breached by the rabbits, and in any case are far too expensive to consider on large sites. Fortunately, rabbit populations are very cyclical, apparently on a five or six year cycle in many cases. This is not of much help to the mine engineer who needs to make every season count, though. In the Buck and Bald mining district northwest of Ely, where rabbits were especially numerous during 1992, large areas of successful revegetation were wiped out. Here I was told by one mine engineer that "a guy really needs a good supply of raptors around here to control the varmints." One way to obtain this is to create suitable perches for hawks, eagles, and owls - the utility poles in the valleys are heavily used by these predators. Except in areas where the presence of sage hens mandates the use of raptor-proof poles, such perches can be erected to standards obtained from the Fish and Wildlife Service or the Nevada Department of Wildlife, although almost any pole with a cross piece will be used. At Pinson mine near Winnemucca, the destruction of many fourwing saltbushes was attributed to the absence of such perches. Here and elsewhere, other methods of control have included spotlighting and shooting of rabbits, which provides some entertainment but limited effective control. The use of poison on public lands is not usually an option, and coyotes are notoriously difficult to either discourage or encourage. Although it is recognized that some fourwing is unpalatable to herbivores, to date there has been no selection of varieties unattractive to grazing. Furthermore, shrubs provide the cover needed to make the rodents secure from predators, so the ungrazed ones in a mix do not necessarily help eliminate vegetation loss. Careful species selection may be of great help, though. Dr. Young recognizes two "pet peeves which are fixed in folklore. . . the use of cereal rye and the use of sweet clover. Both are serious competitors for whatever water is around, and both attract every rodent known to man", he complains. However, in many areas, especially where it is hoped that spontaneous revegetation will occur, the smaller rodents, (but not usually the rabbits!) are a big help, since they move and cache seed in the areas to be replanted.

Other small animals are potentially a problem also. Carpenter and other ants remove many seeds on less disturbed sites, but have not been observed to be a serious problem on mine sites in Nevada. Birds have posed a threat in some areas - at Caliente, some plantings are supposed to have had virtually all the seed picked up by them within a day or two, although prompt and thorough dragging of the surface, or the use of a drill instead of broadcaster, should have prevented this. Grasshoppers have also wiped out sites

in some years, notably in the Elko area in the mid eighties, but have been only a scattered problem.

By far the biggest and most effective threat comes from the large grazers - domestic cattle, feral horses and burros, and deer and antelope. Not surprisingly, cattle and horses cause the most damage. Effective fencing is an absolute prerequisite to revegetative success in almost any area of Nevada except areas of the far south where there is inadequate water to support any hoofed livestock. Depending on wildlife activity in the area, such fencing may be either standard barbed wire cattle fence, or a wildlife fence such as a smooth wire 6" above the ground, followed by three strands of barbed wire at 8", 18" and 34" above this. At Placer Dome near Ely, where the first seeding was totally destroyed after cattle got in and 'hammered' it, a portable electric fence with solar charging of two hot wires with a ground wire between, stretching over 2 1/4 miles, has effectively kept both cows and horses off the tender emerging vegetation. The arrangement is cheap and easily installed, very reliable, and user friendly after one gets used to it. Such fences would also keep burros out, which is often a problem in the south and west parts of Nevada. At Pinson, areas which were seeded in 1989 and 1990 were virtually cleared of grasses after cows invaded the unfenced sites. Green Springs and Illipah, which looked like "a golf course before the cows got here and pounded the hell out of them", were virtually denuded in a matter of days when cows slipped around a supposedly secure rock barrier above a drift fence for a day or so. Although I was told by one BLM botanist that "Cows are lazy animals, they won't climb up on the waste rock dumps" experience and observation confirm that that's not the case- if they are hungry, they will find a way into attractive greenery regardless of the difficulty. This situation was seen over and over again - near Battle Mountain where flourishing Sitanion was wiped out by cattle, near Death Valley where burros munched Spiny Hopsage and other shrubs to the roots at Beatty, on exploration roads at Mill Creek in the Shoshone range where the permittee salted fresh seedings heavily to bring the cattle into the new forage, and almost everywhere else where revegetation was successful enough to be noticed by herbivores. Although the BLM lacks a formal policy about fencing mine sites, range cons, miners, and reclamation personnel almost all agree that it is virtually impossible to get decent regrowth without fencing. But the issue has complications, especially in the case of linear disturbances such as drill roads, where, as Rodney Hannon of the Battle Mountain district says, a good seeding just means that "We are building long linear cow restaurants - and they just moooooooooove right up it until it's all gone!" On the Winnemucca district, there is no policy on grazing exclusion, and "we don't know how we will handle it if the cows get in and eat it all off - whether that will count against the mines or not." In any case, one can't economically fence off the drill roads, and it's tough to remove grazing from whole allotments. Yet on the Elko district, I am told that an accepted wildlife-type fence is a stipulation around all mines for a minimum of three growing seasons after reseeding. At Round Mountain the reclamation people claim that it

is not that expensive to fence the entire site, and "it's a whole lot easier than going out with pickups every day to try and chase them off.

Among the problems with fencing are that no one knows how to determine when to let the cows back in, and who will maintain it until it comes down. According to the state's Pete Anderson, they have no answer to those questions. "We've just been going along with the BLM district's desires. But the perimeter fences will have to come down after reclamation is complete." As I was told by the BLM people in Ely, there is a need for a way to compensate the mines for range improvements such as fences, and that seems reasonable, especially since fences will permit more careful management of revegetated areas which will, in most cases, be of much higher forage quality than the surrounding original range. Thus while fencing is essential to successful revegetation in almost all cases, there are still unresolved issues about how long they should remain, and about the responsibility for maintenance of them after mining activity ceases. Yet with only a few exceptions, both miners and regulators agree that reclamation should not be signed off if revegetation fails because of grazing that could have been prevented with fencing.

Weeds

Definitions of the term weed usually involve the requirement for growth in environments disturbed by man. (Young and Evans). On disturbed mine sites in Nevada, the first and most obvious vegetation is almost always weedy. In the north, cheatgrass is often present, and throughout the state, halogeton and tumbleweeds (Russian thistle) overrun roadsides, waste rock dumps, and other disturbances almost as soon as the ground is turned over. Efforts to eliminate the weeds are rarely successful - one halogeton plant, after all, can produce as many as 250,000 seeds, which may drift like snow into piles a foot deep on waste rock dumps and drill pads. Herbicides, which are probably ineffective anyway, are not usually an option on public lands. Although there has been research into ways of coaxing perennial species to germinate more quickly to get a headstart against the weedy grasses and forbs, techniques such as matric priming and soaking in polyethylene glycol are difficult and expensive, and have not been tried on mine sites in Nevada to my knowledge.

The good news is that once sites are left undisturbed, the weeds are generally self-limited. Furthermore, although conventional wisdom holds that the drier sites are more difficult to revegetate, at least they are usually free of the cheat grass invasion that locks up more moist areas. At Grefco, in west central Nevada, which is in one of the most arid zones, natural revegetation occurs on sites that would certainly be overrun with cheat grass if left unseeded on the more northern BLM districts. Although halogeton and tumbleweeds do appear at first, they disappear within a couple of years, and the native shrubs take over. This pattern is common for these two important weed species throughout the state - they appear in dense stands the first year or so after the land has been abandoned post-mining, but within five years (usually two or three) they are gone with no encouragement from land managers.

The exception to this pattern is cheatgrass, which often takes over large areas, especially in the northern half of Nevada, forming such dense stands that the plant community is effectively closed to any natural or human seeding efforts. Furthermore, the tendency of cheat grass to burn after drying in summer keeps these communities in a primary seral state indefinitely. While this allows managers to keep the land in an ecological "holding pattern" until better seeding techniques are developed, it has also condemned large areas of the state to a monospecific community - either cheat grass or crested wheat grass.

The most practical control of all of these weeds seems to be to quickly "close the window" - as the Northumberland Plan states, "On-site observations indicate that halogeton can be controlled with successful revegetation with other more competitive species. The primary method of control will be seeding of disturbed areas as soon as practicable after the seed bed has been prepared." Even when immediate seeding is not practical, or when the surface is taken over by weeds anyway, it is reasonable to hope that the

halogeton and tumbleweeds, at least, will be a transient and self-limiting successional stage. In many cases, annual weeds will constitute 90 to 100% of the biomass the first year, 50% the second, and 30% or less the third year, as they yield to the longer-lived perennial competitors. This seems to be true regardless of the weed species involved. On Elko's Independence mine, "Our topsoil always gets thistle in the first year, even when we immediately seed with grasses."

Part of the reason for this may be that many topsoil stockpiles, especially those which have not been promptly seeded with perennial grasses or mixes, grow great crops of seeds which no doubt contribute to the seed soil bank and germinate once the topsoil is in its final place. But there are apparently other factors which encourage weed invasion as well. At the Hog Ranch mine, there is an obvious delineation between old ripped haul roads and the berms of those same roads. Despite the fact that both were seeded, the road surface was dense with halogeton and tumbleweed while the berms beside them have good bunch grass and shrub invasion. And at the Santa Fe mine near Gabbs, the topsoil storage piles were covered with tumbleweed as were the seeded areas where topsoil had been spread, but the two areas had different species of this Russian thistle - on the seeded areas barbwire Russian thistle replaced the standard species.

Halogeton and cheatgrass are both mercifully absent from most disturbed sites in the Vegas area, where annual buckwheats tend to dominate recently disturbed sites. At other sites such as Echo Bay on the Ely district, halogeton is sometimes replaced by Lepidium, Nicotiana, and various annual buckwheats. At the Buckhorn mine on Elko district, the weed whitetop is the primary invader. Yet with the possible exception of cheat grass, most of these weeds don't seem to be a threat to revegetation - within a few years they disappear spontaneously in the face of competition from the more desirable perennials. As with many other revegetation questions, the use of test plots will probably identify the extent of the problem with annual weeds in a given area, as well as hinting at whether or not the problem can be expected to correct itself in a reasonable amount of time.

Drill roads / Linear disturbances

"Where we seed clover on drill roads here we are just building long linear cow restaurants and then they moooooooove right up them until it's all gone!"
-Rodney Hannon, BLM Battle Mountain

The BLM Surface Management manual gives general guidelines for the reclamation of roads. For dirt work, trackhoes have proven to be the most efficient equipment for recontouring, sometimes in conjunction with a dozer, as the Santa Fe mine does. At an average of 2.5 acres per mile, there is a great deal of land to be reclaimed under drill roads - Independence alone has already reclaimed 215 acres of road. The basic revegetation technique is the same as for other disturbances, recontouring, replacement of topsoil, ripping or scarifying, seeding, and dragging the surface if the seeding was by broadcast. But there are several considerations unique to roads. One is that it is economically unfeasible to fence them to restrict grazing, with the result that herbivores concentrate on the fresh vegetation, often dooming it. On the north fork of Mill creek on Battle Mountain district, the successfully revegetated roads were destroyed because the cattle operator actually put three salt blocks on the road, to bring the cattle into the new growth! Obviously better education or more conscientious management would have prevented the loss of this reveg effort. Such situations also create difficulty for the BLM in assigning responsibility for the failure of the seeding.

Another problem is that it is sometimes difficult to foresee whether or not the road will need to be reused in the future. There is a 1.5 mile road near Beatty that has been reclaimed three times and is about to be rebuilt yet again, so that it has been built and unbuilt four times in five years. "And it's in a place where we could have expected continued use of it!" This not only wastes time and energy, but causes problems in sorting out who is responsible for what on reclamation.

In northern Nevada, cheat grass is a problem on reclaimed roads, but in most other areas, revegetation is not a problem, except where cattle or horses have destroyed the vegetation. In the steeper areas, good ripping on contour is essential to control erosion.

Throughout the state, including in the cheat grass areas, there are numerous examples of good spontaneous or natural revegetation on properly recontoured drill roads. This is discussed in the section on spontaneous reveg, and may be an option in some areas where time is not too critical a factor. This eliminates most of the potential for cattle problems. Volunteering species include various saltshrubs and sage near Winnemucca, bunch grasses and

phlox on Hog Ranch Mine, shadscale and composite shrubs near Tonopah and Las Vegas, and many other species, shrubs, forbs, and grasses. In areas where the surface is barely scraped, many plants regenerate from the roots which remain, including ephedra and creosote bush. A test plot involving only the dirt work, without seeding, should give a good idea whether or not spontaneous revegetation is likely to occur on a given site.

Many roads in southern Nevada and near Tonopah are not reseeded, on the assumption that seed would fail anyway. This is probably not the case, however, because there are many examples of successful reseeding around. The Kern River pipeline right-of-way, for example, shows dense growth of penstemon, winterfat, and grasses, despite the aridity of the site. Where it was not reseeded on an adjacent success, annual weeds are much denser, and little perennial vegetation is evident. Nevertheless, Tonopah does not require reseeding where precipitation is less than 8 inches annually, and many of the roads here show good invasion by natives.

"We get lots of spontaneous reveg around here - both cleat grass and cleat brush - that's the stuff that comes up in the caterpillar tracks." - Clive Bailey, Buffalo Valley Mine

As Pete Anderson (Env. Manag. Spec., Nevada Bureau of Mining Reg. and Recl.) says, "We've all seen examples of old dumps that have naturally revegetated, but it's not an option for us because we are looking for short-term stability." And of course we've all seen examples, such as at Virginia City, where there are dumps over 70 years old that are growing nothing at all. Nevertheless, natural revegetation is one option in some areas, especially on linear disturbances such as drill roads and right-of-ways. Certain desirable species such as Ephedra and Sitanion and Shadscale, among others, come in more reliably as invaders than they do in intentional seedings. This has been noted on old exploration trenches in Buffalo Valley (Battle Mountain district), at Round Mountain on waste rock dumps, throughout the Ely district, on drill roads near Echo Bay at Elko, and especially in the extremely dry areas in the southern part of the state, such as Beatty and Candelaria. Of course the problem with spontaneous revegetation, besides the time delay, is the unreliability of it, especially on large disturbed areas. Nevertheless, on drill roads throughout the state, except possibly in areas where cheat grass is a severe invader, it may be possible to concentrate on getting the earthwork done well so that erosion is minimized. That would allow adjacent vegetation to move in naturally, especially in shadscale areas. This also avoids the problem of cows camping on the revegetated but expensive-to-fence roads, and prevents the visual disturbance that results when long lines of new and different plants are imposed on an established landscape. (While this is a common problem in many areas, it is dramatically evident in the Independence range on Elko district.) Even in severe cheat grass areas, such as on the Winnemucca district, drill road reveg is rarely a great success for various reasons. Yet with careful use of trackhoes it seems possible in most of the drier areas to do the earthwork in a way that limits erosion long enough for nature to do the plant work.

In southern Nevada, the BLM has rarely required reseeding in most of the valley washes, and reclamation is usually considered complete when the earth has been recontoured. Here various perennial grasses, globemallows, and shrubs such as Franseria and creosote bush are consistent invaders of old surface exploration pits and piles such as the ones common in Eldorado valley and the Searchlight area. The difficulty again is with the lack of consistency. For example, at the Kenoro mine site, the nice recontouring to a rolling topography has resulted in only tumbleweeds and a very few grasses in the last two years, while not far away an older unreclaimed road shows a dense growth of Macaranthera, Eurotia, Encelia, Nicotiana, Dalea, Franseria, Eriogonum, cat claw, globemallow, Indian ricegrass, and other native plants. Since the work on the Kern River pipeline, the explorations at Colorrock quarry, the LAC Bullfrog mine, and other sites demonstrates that intentional reseeding can work very well

despite the aridity of the region, it is probably not appropriate to rely on natural reveg even in this area, unless perhaps it is shown through the use of test plots that it is likely to occur in a timely manner.

In summary, while spontaneous or natural revegetation may be appropriate for linear disturbances throughout the state, it is not a reliable substitute for the reclamation of larger disturbances. These have been shown to be reclaimable through standard reseeding practices throughout Nevada.

Evaluation of Revegetation Success

The lack of consistency and quantification in the evaluation of vegetation on Nevada's reclamation projects has been a source of much confusion in the past. Even such efforts as the SCS mine test plots are routinely evaluated in such terms as "good", "fair", and "poor", which have little meaning between sites and between evaluators. Other agencies and the mining companies have tried to get by with snapshots that show the plants coming up on various sites, again with no quantification. The emergence of the bonding process has made it clear that it is now essential to be able to describe revegetation success in a way that is consistent from site to site, and from investigator to investigator, and from year to year. Only then will the mining companies be able to clearly see how close they are to successful revegetation, or to know when they have achieved it. And only then will the BLM have the documentation needed to withhold or release bonds without the accusations of inconsistency that are now common.

The Winnemucca district has been in the forefront of quantifying vegetative success on reclamation projects. They have used the line intercept method on predisturbed areas, and used 50% of that cover figure as a standard for bond release, which they believe is an achievable figure throughout their area. On other sites, they have used similar standards based on quantitative analysis, such as in the Cosgrave plan, where the criteria have been established as: "A minimum of five perennial plants per square meter, one of which is a shrub. . ." and "When the reclaimed sites have established a 12 percent vegetative canopy cover." Other mine sites use other figures, but in all such cases, the results are not vulnerable to the subjective differences between evaluators and seasons.

On the Kern River pipeline right-of-way on the Las Vegas district, plot frequency transects are run, using hoops. Tonopah has used line intercept extensively. Here the personnel are very aware of the problems with subjectivity, especially since the continuity of project supervision is so often interrupted by personnel change and transfer. This complaint has emerged repeatedly, as on the Elko district where I was told "We go out, we look at the plants, and we look at the site. It's a judgement call - 'yes, it looks good, you can have your bond back', or 'no, it needs more work'. We really need objective criteria."

Other examples of quantified vegetative success standards have been proposed by the mines themselves in many cases. One such is at Magma's Robinson project, which specifies: "Establishment of vegetation with a 30% canopy coverage of the surface. No more than 5% of this cover may be noxious weeds. Diversity of cover shall be as follows, based on total vegetation occurrence: At least 33% must be perennial grasses; at least 17% must be forbs (noxious weeds are not to be counted in this percentage); at least 7% must be shrubs, with no more than 50% rabbitbrush. The above

percentages include both planted and native growth. The remaining 43 % of the total vegetation can be any combination of the above, including weeds." The standards go on to specify that conformance will be determined either by the line intersect (sic) method or the step point transect method as described in the BLM technical reference on "Rangeland Monitoring Trend Studies", and will be done at a rate of three transects per stratigraphic feature, or one per 160 acres, whichever is larger. Stratigraphic features are described as areas that change vegetative success due to slope, rainfall, aspect, and soil type, or different mine features such as haul roads, leach pads, tailings, and waste rock dumps.

Fortunately, there is now a BLM task force on bond release criteria which is addressing these concerns. The first meetings, held in December 1992 in Reno, were very promising. It appears that there will soon be statewide standards for vegetation analysis and the setting of quantified release criteria, which should eliminate the criticisms about lack of consistency on the part of regulators. These standards will probably be based on foliar and basal cover by line intercept.

Excellent technical references have already been published by the BLM which contain all of the information needed to determine which analytical method is appropriate and how it should be implemented. The reference card "Vegetation Attributes", by the BLM's Phoenix Training Center, lists various parameters or attributes such as density, frequency, production, composition, and the various measures of cover. It then defines and gives the applications, advantages, and disadvantages of each attribute from various management standpoints. All of this is presented in a clear format which does not require extensive biological training to understand and use. The BLM Technical Reference 4400-4, May 1985, titled "Rangeland Monitoring Trend Studies" defines the methodology to be employed in setting up various analytical plots. There are also many textbooks on vegetation analysis which provide instruction in standard techniques.

Another factor where the lack of consistency causes problems is with the frequency of inspection. The state tries to visit each site yearly at first for reclamation checks, and more often as it gets underway, but expects problems with this. "we are staffed for it now, but the crunch will come after the April permit deadline - there will sure be a lot of work next summer!" The BLM, even shorter on staffing, varies greatly in frequency of inspection from district to district, with the goals ranging from once every month to every 2 or more years. Since FLPMA requires the BLM to keep a current inventory of public land resources and other values to reflect changes in condition and to maintain and make available to the public an inventory of range condition and trend, some policy is obviously needed here also. It seems most reasonable to plan inspections around the time of initial seeding to look for obvious problems impending, and again early in the first growing season and at the end of the first growing season, to see initial success, and at least once each growing season thereafter for followup. The

bond release task force is also considering this issue.

Many have complained that it is impossible to see the small seedlings so early, but there are several techniques that make them easier to find. It is obviously important to know what the individual species look like, which requires not only a knowledge of what was planted, but what the young plants look like. Unfortunately, there is not yet any easy-to-use field guide to young seedlings, although the SCS has produced such guides for conservation species in the midwest. A poster of photos of the various commonly used species could be developed and would be of great help. In the absence of such aids, mines can develop their own collections of pressed and mounted herbarium specimens to aid in further identification of species. These need not be elaborate, expensive, or in perfect scientific form. Round Mountain has an excellent stack of such specimens, representing most of the planted species, native species, and weeds likely to be encountered on their revegetation areas. Another important practice in finding small seedlings is to get out of the truck and get close to the ground. While this may seem obvious, there were many occasions on which the mine and BLM personnel drove past a seeded site, telling me that it was a failure, although when we stopped anyway and got out to look closely, many seedlings were evident. Other tricks, especially effective with grass seedlings which are often nearly invisible even closeup with good light, are to use a flashlight at night, or to look at the sites closely while holding a sheet of white paper close behind the spot you are examining, which makes the seedlings stand out very clearly.

Finally, it must be noted that with very few exceptions, accurate and accessible notation of revegetation methods and results is almost absent in the Nevada mines, which means that most of the information available has been permanently lost and many of the mines have condemned themselves to just repeating their past mistakes without even realizing it. While some solutions to this problem will be addressed in detail in the section on test plots, general suggestions here include the following: The boundaries of various treatments and seedings need to be clearly marked in a way that allows them to be specifically identified and located for some years afterward. It is surprising that an industry that has dotted the Nevada landscape with an estimated 2 million relatively permanent and visible white PVC claim posts should have settled on the thin wooden stake-and-pencil method as a standard for marking reclamation efforts. It is very uncommon for such stakes to remain in place and legible for more than a season or two. When the stakes are no longer in place, the information is also gone, since there is no way to know what was done or not done in a given area. Metal stakes, claim posts, rock cairns, or any other permanent marker with a label that allows it to be keyed to a written record should be immediately made standard for delineating all test plots, reseedings, and other reclamation treatments.

Along with the lack of effective marking goes the lack of effective record keeping which characterizes Nevada mine reclamation efforts.

In case after case, no one could figure out what had been done on a site, what seed mix was used, or even when or if seeding had been done. The few exceptions showed that 1) Effective record keeping need not be complicated, time consuming, or scientifically formatted, and 2) That a file box filled with receipts and random notes is no substitute for a coherent record. The few exceptions where effective records do exist are not confined to the large mines with extensive reclamation projects, although there are several of these, such as Barrick and Pinson where the material is well organized and accessible. While such files are definitely the best, even simple journals, such as are kept by LAC Bullfrog, in which entries note the date, conditions, and results of various seedings and tests, provide a means to look back and determine what is and is not working. Such journals are also easy to carry around the project, and eliminate the common problems with misplaced data that occur in sophisticated, computer-based recordkeeping which require the extra step of data entry later. Even simpler than such an activity journal, and still useful, is the running clip-board style commentary such as Grefco maintains, which lists dates and methods of planting, species planted, and any treatments used. This has been compiled into a very useful book which also includes soil analysis results, maps, actual seed samples, photos of work in progress, and photos of mature plants on the project. Of course, the more accurate and detailed the record-keeping, the more accurate and detailed the conclusions that can be developed and the better the learning process. However, a system that is too detailed to be easily interpreted and related to what is on the ground for the personnel that will be using it will also go unused. Specific suggestions and layouts for various methods of record keeping can be found in the test plot section, since the needs there are the same as for larger-scale reveg efforts.

Special situations: Dust Palliatives

Most dust control on mining operations in Nevada is accomplished by water truck spraying. In some cases, usually on pads and haul roads, a magnesium chloride solution has been used. The resulting chloride contamination of the soil is a problem in reveg efforts. Where mag chloride-treated areas are to be reclaimed, the approach used by Newmont is probably best. This involves an eight-inch or thicker layer of substrate over the road surface, then the topsoil layer. The topsoil is ripped down to, but not through the substrate, which then acts as a barrier to the chloride. What will occur when shrub roots penetrate the substrate layer is not known yet. New ground water regulations may eliminate the use of metallic chloride salts for dust control, but many people, such as Gary Goodrich at Barrick, feel that it won't be used much in the future anyway. "We have a guy in the engineering lab who looks at nothing but dust control substitutes, such as soybean products. I think that we'll see all the mines getting away from mag chloride as they look ahead more to reclamation. It just loads up the soil and it doesn't help with our storm permitting process either."

Special situations: Problem soils

Although there are areas of saline and alkaline soils in mining areas of Nevada, I am not aware of any revegetation efforts on them yet. The Surface Management Manual discusses such soils in Chapter 7. One area of serpentine soil associated with a mine occurs at Candelaria and is causing some reveg challenges there. In areas of unknown or unusual soil characteristics, a careful look at adjacent natural vegetation and a test plot which matches those species as closely as possible is probably the best answer.

Special situations: Artificial Desert Varnish

This product, called Permeon, was described in the NMA Symposium proceedings published under the title "Successful Mine Reclamation -What Works" (1992) Although it does not stabilize slopes or assist revegetation, it may have limited applications where rock scars impair visual integrity because of the color of the disturbed material.

Angle of repose dumps

Angle of repose rock dumps are one of the most controversial issues in Nevada mine reclamation. Although very few are now allowed to be built - in cases where the mine encroaches on private lands or cultural sites, for example, there are many from the past awaiting the possibility of revegetation. The state's position is that where topography and spatial considerations require it, "we are going along with angle of repose, but we want terraces and this does not release them from revegetating the face." The BLM also requires that slopes be stable and able to be revegetated. "We have no actual slope stipulation [on the Battle Mountain district] but if it's not stable and replantable, they may have to redo it, so they might as well do it right the first time." Nevertheless, there are many cases around the state where it appears very unlikely that such dumps can ever be revegetated. For stability, many of the faces require rock armoring which provides no plant habitat, and even without this, most of the slopes are too steep for any sort of revegetation labor. Barrick has had some success with hydroseeding of wheatgrass and burnet on steep slopes along their entrance road. At Independence, a technique involving broadcast seeding followed by dragging a chain across the face from a cat on top of the dump before hydroseeding has also worked, but both these cases involve topsoil or at least adequate fines and would not be effective on rock dumps. Natural reveg of highway and railroad angle of repose slopes can be observed in many areas, even in the driest parts of the state near Grefco and south of Las Vegas, but always where the material is fine textured.

Development of shrub species transplants may be the solution to revegetation of rock slopes, but it is critical for such transplants to have good soil contact, which will be difficult to ensure. Likewise, transplant crews will have to work on safety lines anchored outside the unstable areas to meet safety criteria, and will find the work slow and dangerous. It may be possible to hydroseed rocky slopes with a strong irrigation spray following to wash the seed into contact with soil between the rocks. Rabbitbrush, zigzag bush, desert peach, and ephedra are likely candidates for success, but have not been tested in this manner. Grayia also shows some promise, since it germinates well in coarse rock where it takes advantage of the moisture which condenses there.

The U.S. Forest Service is conducting research into angle of repose revegetation now. They are undertaking a five year project which proposes to experiment with seeding by broadcasting or mixing with topsoil dropped from the top of the dumps, site prep to reduce erosion, fertilization, mulching, erosion blankets, and hydromulching, among other things. Whether the results of this study will be successful, and if so whether the techniques will work when transferred to the drier sites typical of BLM lands, remains to be seen.

The real solution, according to most people with experience in trying to revegetate steep slopes, is to reduce the slope wherever possible even if this is expensive. They point out also that the steep slopes are what stand out visually from a distance anyway, with or without vegetation. In most cases it is possible to design the slopes with terraces so that at the end of the dumping it is possible to just knock off the edges of each terrace from above and end up with a final slope of 2.5 or 3 to 1. This has been done already at Atlas and elsewhere. Where angle of repose is unavoidable, it may not be possible to revegetate.

Acid Drainage

"You'll like our little town - on a quiet morning you can hear all the Chevys rusting in unison" - sign on pump at Goldfield Chevron.

Throughout the western U.S., the related problems of acid mine drainage and sulphide minerals have plagued hardrock mines. In the Humboldt river drainage alone, ten large mines are either intercepting the water table or are expected to do so soon, posing potential ground water contamination problems. There are no other examples of such extensive pit dewatering situations in this country - some of these pits are projected to cover more than one square mile of surface area and involve the pumping of more than one-half million acre feet of water each. The resulting holes in the ground, as they refill after the mines are closed, will hold as much as 200,000 acre feet of water each, for a total of 700,000 to 1,000,000 acre feet of water. The U.S. Forest Service, which identifies acid mine drainage as "the most intractable and costly reclamation problem it faces with western metalliferous mining operations", has identified over 1500 sites on their lands alone throughout the west with significant acid mine drainage problems. Yet Nevada's BLM lands seem to have few such problems. One reason for this may be that the Nevada Administrative Code notes that "If you [a mining operation] give as your conclusion that the mining activity - i.e. refilling of the pit with water - will have a detrimental effect on the ground water of the state or the well-being of humans or animals you will be denied permits to begin construction and operation." - which is obviously not the sort of statement that encourages an objective assessment of the potential for acid drainage problems by the mines. Therefore most of the mines deny that there will be a problem with acid drainage, despite the controversy surrounding the issue and the lack of research or experience in Nevada on which to base such conclusions. Nevertheless, some engineers have admitted that their pits are expected to hold acidic water when pumping ceases (Carlin trend/ Newmont per Smithson), while others immediately adjacent (Barrick) apparently do not feel that the potential exists. Nevertheless, the problems with acid drainage have emerged at a few sites, some of which are recent rather than in the historical past.

The BLM's Nevada Surface Management / Solid Mineral Reclamation manual identifies various indicators of potential acid site problems, such as the presence of ferric hydroxide precipitate - known as "yellow-boy" from its orange, yellow, or purple color, on watercourse bottoms, or the absence of vegetation and animal life, or the sulphurous smell, or the presence of metallic pyrites in disturbed materials. While Nevada does have some sites, most

notoriously the Leviathan mine where the pH is around 3.0, that nothing will grow on, for the most part, acid mine waste is probably not a big problem. Even sites such as Round Mountain, where sulphide ores will be mined, often have high levels of CaCO3 which are anticipated to eliminate the potential for acid generation. One possible acid site will be at the Sixteen to One mine above Silverpeak, which will apparently have to do ore and waste rock characterization tests for the NDEP before starting their new pit, but most potential problems have already been in operation for some time. At the Magma site on the Ely district, where sulfuric acid may be present, BLM personnel have suggested that the acid-generating material be compacted and covered with ten inches of crushed waste rock followed by six inches of topsoil. It will be interesting to see how the vegetation reacts once the roots penetrate this 16 inch barrier to the acidic medium. The best solution in most cases is to design the dumps so that potentially 'bad' material is buried deep inside - an idea which is being implemented at Rawhide and various other sites.
According to John McLain, it may be advisable to use clay or bentonite to create an impervious layer over acid-generating materials even when they are buried since the Office of Surface Mining is unlikely to "sign off" acid wastes in the future without this.

Wildlife

"Wildlife is a dirty word around this mine right now. The ringtailed cats that live under the engineer's shed got into the lab last night and crapped all over the AA unit!"
- Dean Warner, Candelaria mine

Enhancement of wildlife habitat is the second most common goal in mine reclamation in Nevada. Indeed, even without such management, many mine sites are proving very attractive to various game and non-game species. Chukar, which apparently grow very large on many mines, are frequently seen by the hundreds on the Candelaria and Buckhorn mines and others. Doves, ravens, rattlesnakes, hawks, eagles and owls, as well as deer and antelope, are frequent residents on many mines. Yet the presence of wildlife, especially if it is a 'listed' species (Rare, endangered, or threatened according to the U.S. Fish and Wildlife Service) is not always good news. The best example of this may be the "Goshawk Rebellion" in the Elko area, where a broad-based coalition developed in response to activity restrictions imposed by the Forest Service in an attempt to avoid disturbance of nesting activity. Nevertheless, mining activity, especially when it involves the creation of highwalls, most of which will remain long after the mines are gone, seems made to order for certain types of wildlife habitat development. At First Miss/Getchell, for example, creative blasting to increase nest sites is under consideration. At the same time, a plan to salvage a golden eagle nest for later replacement may or may not be successful. However, the creation of rock piles for rodent and reptile habitat on top of recontoured waste dumps, especially if combined with the addition of trees or poles for perch and nest sites, seems certain to improve both predator and prey population levels at the mines which are creating them. Such rock piles at Relief Canyon, Independence mine, and several other sites, provide the shelter and vantage points which are otherwise absent on disturbed and recontoured sites. At Hog Ranch, in northern Washoe county, marmots moved into such piles almost immediately, attracting hawks and eagles which are almost always visible around the mine.

Slash piles, where the slash is available, also attract many species. (At Independence such piles are referred to as "the squirrel condos".)

In South Dakota and other states, selective blasting of high walls and pit benches to create nest sites, crevices, and talus slopes for wildlife is common practice. In Nevada, though, wildlife efforts are often more directed at keeping the animals out of harm's way, perhaps because of the newness of most of the current operations. This takes the form of tortoise fences in the southern areas, and of avoiding the planting of yellow sweet clover and other wildlife attractors near haul roads and pads. As more operations enter closure, perhaps the emphasis will shift towards

plantings and topographic arrangements which favor wildlife, such as are mentioned in the USDA "Wildlife User Guide" GTR INT-126. Certainly the potential exists to recreate the landscape and vegetation in ways that favor various types of wildlife, since the process is being done "from scratch" in most disturbed mine sites anyway. It will require encouragement from the regulators, especially in the form of recognition that wildlife habitat may be a very important goal in reclamation, one that potentially has a higher economic value in many areas than simply restoration of a naturally limited domestic grazing potential.

Tailings

"The two big mill products down here around Vegas are scamnesium and bogusite - the mining is in the investors' pockets" - Joel Mur, BLM Las Vegas

Many mining operations in the state don't mill ore, thus avoiding problems with the revegetation of tailings. The BLM manual supplement to the Solid Mineral Reclamation guide lists a number of criteria to be considered in the reclamation of tailings, including actual and projected pH, chemical (including heavy metal) contamination, salt migration, and fugitive dust. Of these, the most obvious is dust. . . at McGill on the Ely district, it is said that on windy days the whole town disappears in a cloud of blowing tailings, despite years of attempts at irrigated revegetation. Across the state at the Winnemucca district's Getchell/First Miss mine, old tailings blow so ferociously that the shrubs and bunch grasses downwind are sand-blasted off at grade level, and plows are periodically sent out to dig out the four-strand fence so that the cows can't walk over the top of it and get into the reseeded areas. Many of these tailings impoundments are quite large - at Barrick Goldstrike over 30 million gallons amount to about 100 acre feet. There a test is under way to determine the feasibility of decanting off the liquid and depositing more slurry until there is a three-foot deposition, which will then either be covered with waste rock and topsoil, or plain topsoil with four different treatments tested in all. Next door at Newmont, the plan is to incorporate thirty tons of straw per acre into the tailings with fertilizer, in hopes of creating a usable growth medium in situ. The Pinson approach, though, is probably the most conservative and widely used. The tailings pond is just capped with material that would have gone to the waste rock dump, which is then either topsoiled or not, depending on texture and supply, and revegetated conventionally. This approach has been used even in cases where reseeding is not anticipated, such as at Cypress Tonopah, where the blowing tailings are mostly on private land and are being covered with material from gravel pits to satisfy state requirements on the control of fugitive dust. Here there seems to be no point in actually topsoiling the tailings, since the top layer of material is "bug dust", which beads up when watered and blows away just as the tailings do. Here the tailings dam is being invaded by shadscale, Eriogonums, bursage, and Stephanomeria in addition to the usual tumbleweed and halogeton, and it will be interesting to see what ends up growing in this unseeded area. Other tailings dams in the area of this older molybdenum mill operation were broadcast seeded with various shrubs, grasses and forbs - the unfertilized areas are showing many small shadscale although the mine comments that "most of what is out here has nothing to do with our seeding yet", while the areas treated with fertilizer and hydroseeding have a heavy crop of tumbleweeds with no perennial volunteers in evidence yet. The tumbleweeds are

closely associated with the use of fertilizer here. At Getchell/First Miss, which mines primarily arsenic sulphides, which are mined in only one other place in the world, in Siberia, it is still only the mechanical sandblasting which limits vegetation - "when we get the sandblast controlled both the natives and our plantings thrive". This is done by covering the old tailings with the strongly weathered granitic pit run material and fertilized with urea and phosphorus. Where the surface does not form too much of a hard crust, the approach seems to work well with broadcast seeding and dragging. Although there is some concern about plant mortality once roots reach through the covering material, the easiest and most reliable approach to tailings revegetation is to simply cover with waste rock or pit run material, followed by top soil or growth medium which is then revegetated like anything else.

Leach Heaps

The revegetation of ore heaps after leaching is complete is one of the biggest unknowns in Nevada mine reclamation - to date not one heap has been closed in the entire state, although several are being rinsed down in preparation for closure. The state, as usual, expects to follow the BLM's lead on the issue, after determining that the heaps have been rinsed to the point that there is no threat of contamination to the waters of the state. Although there is some dissent in the BLM about whether or not to require reveg of heaps, especially in areas where no topsoil is available, most of the mines are expecting that there will be little difficulty in doing so. As Barrick Goldstrike says, "We figure that the results from the waste rock dumps will dictate how we handle the leach pads, since it's basically the same material even though it's a little finer. We plan to just knock the slopes down to a maximum of 2.5 to 1 and lay on enough topsoil to get a 12 inch layer on all of it." Even though no heaps have yet gone through closure, there are several experiences which suggest that such an approach will work. One is a Dee Gold, where the heaps have been seeded with grasses and legumes during the rinsing process. These species, which are thriving on the irrigation from the rinsing, are not expected to survive the drier, post-closure conditions, but will be plowed in as a green mulch fertilizer before the final seeding. In the meantime, though, besides adding organic material and microflora to the heaps, they are demonstrating that there is probably not going to be a rude surprise awaiting the final reveg effort. Even more interesting are the test plots at Cominco's Buckhorn mine, where several large loads of heap material were hauled out before leaching to serve as a test plot. This site, which was set up three ways, with thin topsoiling, thick topsoiling, and no topsoil, and various mulch treatments, is an extremely lush oasis of shrubs and grasses in the near-desolation of the easterm edge of the Cortez mountains. Even where there was no application of topsoil, the fourwing saltbush and Great Basin Wild rye are thick. Other grasses also flourish, especially where mulch was applied, although sage and rabbitbrush, included in the seeding, did not appear.

Other mines expect to follow a similar recontour/topsoil approach to heap revegetation. At Newmont, on the Carlin trend, the heaps will be knocked down to between 2.3:1 and 3:1 per BLM requests, after detox is complete. Here, as at Winnemucca and elsewhere, it is expected that reseeding will be no different from waste rock dump treatment.

Obviously the use of a small amount of heap material prior to leaching, while perhaps not exactly duplicating the chemistry of the material at the end of the mining process, has the potential to provide very valuable information about soil preparation and seed

mixes, just as other test plots give, and should be done as a routine part of the test plot process at any mine facing the eventual revegetation of leach heaps.

Technical Assistance

"When you look over on a hot day and see all your working dogs soaking in the creek, remember that there IS a dog union and they DO have SOME leverage!" - Dr. J. Young

Lack of technical or expert assistance is strongly felt at nearly every level in Nevada mine revegetation. Both the mine and BLM personnel that deal with the issue are nearly always geologists with little or no training in plant science. Although most of them have picked up considerable practical knowledge in the course of their involvement with the subject, there are few that have any scientific background to help them in getting things to grow or knowing what can be expected in revegetation. One BLM reclamation specialist summed it up by telling me "They are taking geologists and putting them in charge of reclamation - we don't know the plants. In fact, we aren't even supposed to look at the soils!"

Most of the mine labs are capable of doing the soil analyses needed to determine fertilizer recommendations and detect other chemical problems. Commercial labs are also available for this. The advantage of using the outside labs is that they have the background to interpret the results and suggest solutions.

There is also much confusion about the determination of seed mixtures. Except where consultants are employed, (and sometimes even then) seed selection is haphazard and often impractical. On most districts, the BLM personnel are now offering suggestions to the mines on seed mixes. That approach, based on experience, is certainly the most likely to result in successful and reasonable choices.

The Battle Mountain district has a series of standard mix recommendations based on site elevation and precipitation. On the Carson district, a data base is being developed that will give specific suggestions when a series of site parameters are plugged into it. The SCS is apparently planning a similar computer program for the entire west, although that may be some time in development. Such approaches should greatly enhance revegetation success in Nevada, since they will incorporate a wide range of observations and experience. In the meantime, the SCS has information about seed choices available from its several test plots in mining areas around the state, and can offer it to both the BLM and the mines upon request.

Another important source of expertise as well as plant material is the Northern Nevada Native Plant Society, which publishes articles and a newsletter, conducts monthly meetings and field trips, and has a seed collection and exchange program. NNNPS, POBox 8965, Reno, Nevada 89507.

The California Native Grass Association emphasizes restoration based on native grasses and associated plants. They are a good source of information on all aspects of the uses of native grasses.

P.O. Box 566, Dixon, California 95620.

There is great variation between districts in the amount and type of expertise made available to the mines. On several districts, such as Winnemucca and Susanville, there is a team approach which pools the knowledge of numerous people and specialties on each project. Elsewhere, the projects are doled out individually as they appear, which keeps one person familiar with each project but discourages transfer of learning between personnel. In the absence of a ready supply of outside expertise, the team approach certainly results in the greatest chance of revegetation success, especially as the mines increasingly rely on the BLM for their information about revegetation.

Several BLM personnel have suggested that a regional team is needed to make the rounds of both the BLM and the mines to help standardize the approach to revegetation and to show the mines how to accomplish it. Others have suggested some sort of revegetation certification similar to the cyanide training, which would be required of anyone facing revegetation on BLM lands. This might include selection of plant materials, seedbed prep, erosion control, planting technology and calibration, quality control, weed control, seedling identification, grazing management, and evaluation techniques, among other considerations.

Remote Sensing

> "There is tons of gold in these hills but no one has ever seen a speck of it - it's all finer than smoke" - Don, Atlas' safety officer.

Although many mines and BLM personnel are using photos to document the progress of revegetation efforts, remote sensing has not been used to track plant regrowth on mine sites in Nevada. In the BLM there is concern that a system using remote sensing to evaluate revegetation would turn out to be too complicated, and would be just one more piece of expensive equipment that would end up unused and gathering dust, as has happened with GIS plotters when no personnel were given time and funding to run the system. Nevertheless, GIS is used by Newmont, and perhaps others, to do predictive geology. Newmont is especially interested in using remote sensing to quantify vegetation success over large areas of the mine. Barrick has recently taken high altitude photos of their area, which may be of use for vegetation analysis. Due to budget constraints, the BLM has not flown aerial surveys in most areas for some time, and have only used them to divide up reclamation responsibilities on projects which are changing hands.

Despite concerns about a remote sensing system being so sophisticated that no one can actually use it, George Stevens, a well known exploration geologist in the Vegas area, does not agree. He has had extensive experience with the use of high altitude and satellite imagery in military intelligence as well as mining, and feels certain that it can be used to monitor and quantify vegetative success. He feels that with the satellite overflights and various high altitude infrared photos, there is all the information one needs available - it just involves learning the techniques to read it. This is within the reach of typical mine and BLM personnel. He claims that it will distinguish annual from perennial plants, show drought stress or chemical contamination problems in the plants, and allow one to localize a site to within six feet of it's actual location on the ground. He is certain that high altitude IR can be used to evaluate revegetation to see if it meets criteria for bond release - for example, whether there is 25% perennial cover or whatever. "The technology has been there for a long time - the uses are showing up now."

There is still some debate about that, though. Dr. Paul Tueller has been working on remote sensing of arid land vegetation for many years at the University of Nevada. "It is possible to use various satellite radiance based vegetation indices to predict plant cover. What is difficult to do now is determine the quality of that vegetation and its long term persistence. . . It is possible to do but needs some additional research before it will be practical for determining vegetation success for the satisfying of bonds. . . a reasonably inexpensive remote sensing system might be within the reach of most mining companies. I might suggest a system with the following: 1. A PC or UNIX based image processing system with GIS capability. 2. A multispectral airborne vertical video system.

The video data can be acquired whenever the mine feels the need to examine the mine environment. The data can be easily stored for future use. I think such a system could be acquired for less than 30K and could be used for a number of different activities. The video is useful because of its real time or near-real time capabilities and the fact that it is now getting to be almost as good as color aerial photography with is much more expensive to obtain on a one-time basis. Once the hardware and software are acquired the cost of new images is basically only the flying cost."

Others, such as Dr. Tom Lugaski of the University of Nevada, feel that "when you are doing remote sampling from Landsat images, if the cover is less than 25% you are just sampling soil. Above that, you can do all sorts of things with it. With high altitude IR is difficult to get quantification of all the different species. With U2 images you can identify every species out there, but at $25,000 per hour it gets pretty costly!"

Thus is seems likely that while remote sensing will soon be an option for analyzing the success of mine reveg efforts and the trends on revegetated areas, there is still some work to be done before it is fully practical.

Appendix A

List of sites visited during 1992/1993

Susanville District:
- Western Hog Ranch mine
- Exploration sites unnamed

Elko District:
- Barrick/Goldstrike mine
- Newmont mine
- Independence - Jerritt Canyon mine
- Cominco - Buckhorn mine
- Exploration sites unnamed

Carson City District:
- Paradise Peak
- Santa Fe mine
- Borealis mine
- Cerro Duro pit
- Candelaria mine
- Exploration sites unnamed

Winnemucca District:
- Winnemucca mountain (post-fire site)
- Pinson - Preble mine
- Getchell - First Miss mine
- Clearwater site
- Exploration sites unnamed
- SCS test plots

Battle Mountain District:
- Atlas mine (with SCS personnel)
- Buffalo Valley mine - Horizon gold
- Echo Bay mine - McCoy Cove
- Beacon Hill Pit
- Mt. Hope explorations
- Bat Claims
- Mill Creek - Bond gold explorations
- Rocky Canyon explorations
- Exploration sites unnamed

Tonopah:
- Round Mountain - Smoky Valley Common operation
- Manhattan
- LAC Bullfrog mine - Rhyolite
- Grefco Diatomite mine
- Goldbar/Angst mine
- Cyprus Tonopah molybdenum mine
- Tonopah townsite mines
- Corona - Hill of Gold explorations
- Lone Mountain explorations
- Exploration sites unnamed

Ely District:

- USMX Green Springs mine
- USMX Casino mine
- Placer Dome - Bald Mountain mine
- Illipah
- Echo Bay Golden Cross explorations
- Billiton explorations
- Exploration sites unnamed

Las Vegas District:

- Colorock quarry
- Kenoro mill site
- CLC mill site
- Kern River Pipeline Las Vegas area
- Kern River Pipeline Red Rock area
- Searchlight notice sites
- Laughlin notice sites
- Eldorado Valley mill and mine sites
- Nationwide Heap Leach - Searchlight
- Buffington pockets area explorations
- Mill and exploration sites unnamed

Other visits:

- NDOT offices, Carson City
- George Stevens, Nelson area
- State Dept. of Conservation and Natural Resources
- SCS Offices - Reno
- Nevada Division of Forestry offices and Washoe shrub nursery
- USFS Supervisor's Office
- Dr. Paul Tueller, UNR
- SCS Diamond Valley Test Plots
- Various farms near Eureka re seed production (With Extension and SCS personnel.
- Various BLM offices